MILITARY WORKS HANDBOOK

[FOURTH EDITION.]

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ALLAHABAD

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1908

PREFACE TO FIRST EDITION.

THESE Specifications, Specimen Calculations, and Detailed Drawings, have been prepared for the Meerut, Agra, Bareilly, and Morar Divisions of Military Works, in order to facilitate work, and to ensure uniformity in the various offices.

The Specifications may be treated as Standard Specifications; and, whenever they are applicable, it will only be necessary for the Executive Engineers to refer to them in the preparation of projects.

The Detailed Drawings and the Tables given in pages No. 119 to No. 127, (and also "Bull's Tables of Scantlings,") may be made use of for annual repairs and for minor projects; but, when any large or important works are concerned, it will be necessary to furnish full calculations and detailed drawings.

Spare blank leaves have been included, in order that manuscript drawings and notes may be added hereafter from time to time.

R. TYNDALL, M.I.C.E.,

Supdg. Engineer 3rd Circle Military Works.

PREFACE TO SECOND EDITION.

The First Edition of this Book, as shown in its Preface, was drawn up by Mr Tyndall, when a Superintending Engineer of this Department, for the guidance of the Officers of the Divisions in his own command.

But its value was soon widely recognized, and it came into general use, not only in the Military Works Department, but in the whole Public Works Department.

On the First Edition becoming out of print, a revision of the book, and not a mere reprint of it, was found to be required; and Mr Tyndall, being about to retire from the service, arranged that the revision should be undertaken by this Department.

This has now been carried out under the supervision of Colonel Ward, R.E., assisted by Captain Turner and Lieut. Tanner of the Royal Engineers.

The original work has been fully adhered to as the basis of the Second Edition, the revision that has been made lying in such alterations and additions as have become necessary from the orders, types, or standards that have come into force since the First Edition was published.

J. J. McLEOD INNES, Col., R.E.,
Inspector-General Military Works.

PREFACE TO THIRD EDITION.

The reprint of the Second Edition of this Book being exhausted a new Edition has been prepared.

The Tables, Formulæ, and Specifications have been carefully revised, and a good deal of new matter, particularly with reference to Water supply, has been added; the Book now forms a complete compendium of information on all kinds of work ordinarily carried out by the Military Works Service.

The work is based on the Handbook drawn up by Mr. Tyndall for the Executive Engineers of the old 3rd Circle of the Military Works, and is not intended to supersede standard works on the subjects dealt with, but merely as a Handbook for use generally in the preparation of estimates.

S. C. TURNER, Major-General,

Director-General, Military Works.

PREFACE TO FOURTH EDITION.

Owing to the great demand for this Book, a Fourth Edition has become necessary sooner than was anticipated.

The Tables, Formulæ and Specifications have again been carefully revised and important alterations made, specially as regards the temporary loads and wind-pressure to be adopted for roof calculations, the constants for timber in Table V and the safe strains for steel.

Tables of strength of Steel Tees and Angles of British Standard Sections have been added and the Tables for Scantlings, Straps and Bolts for trusses omitted.

The chief alterations in the Specifications have been in the articles on Painting, Road Metalling, Asphalte Flooring and Pumping Machinery which have been rewritten.

New Specifications have been incorporated for the LeMesurier system of roofing and for cement concrete over lime concrete floors. The Specifications of Steel and Wrought Iron Work for Bridges, Trusses, etc., and of Cast Iron have been omitted as these are contained in P. W. D. Code, Vol. II, Appendix 30, Schedule C.

No article on Steel Concrete is inserted in this Edition as a report on this subject by Major Stokes-Roberts, R.E., has been recently printed and can be obtained from the office of the Director-General of Military Works, Simla.

H. W. DUPERIER, Major General,

Director General Military Works.

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PART I.

SPECIFICATIONS.

SPECIFICATIONS.

These Specifications are general ones for guidance in the execution of work throughout the Department they are not intended to supersede Divisional Specifications where such exist duly approved by proper Authority

Earthwork

1 **Excavation.**—*Excavation for Foundations, Earthwork, &c* —The excavation for foundations is to be in exact accordance with the plans, sections, &c, furnished, and care must be taken that the bottoms of the trenches are perfectly level, both longitudinally and transversely, and that the steppings, where indicated on the plans, are strictly attended to

2 If the excavation is in earth, the bottoms of the foundation trenches are to be well watered and rammed, care being taken that too much water is not used, or soft mud may be formed, and if such ramming brings to light any soft or defective places, a report is at once to be made to the A C R E, and the holes should then be filled in with concrete, or be treated in such a way as he may direct

3 When rock has to be excavated, the lower surface of the trenches must be made as level and true as possible in accordance with the plans and the A C R E's directions must be taken as to the filling in with concrete of any small inequalities which it might be difficult or expensive to level

4 No material excavated from foundation trenches, of whatever kind it may be, is to be placed nearer than one foot to the outer edges of the excavation

5 As soon as the foundation trenches are completely excavated in exact accordance with the drawings, (or as directed by the A C R E,) and made ready in other respects as above described, a report is to be made to the A C R E to this effect, in order that he may make a

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final inspection of the work, and that he may give orders for the commencement of the building of the foundations. Without such inspection, accompanied by the A. C. R. E.'s written permission given to the Contractor or Overseer in charge, the building is not to be commenced on any account.

6. **Earth filling, &c.**—As soon as the building is finished to the top of the plinth level, the space between the foundations and the side of the foundation trenches is to be cleared of whatever *débris* may have fallen therein, and is to be then filled in with earth laid in 9 inch courses, and rammed.

7. As soon as the superstructure of the main walls is 2 feet high above the plinth level, the plinth may be filled in with earth in 9 inch courses, watered and rammed; and a sufficient depth of this earth may afterwards be removed where required, so as to make room for the specified flooring.

8. On completion of the building, the ground all round to a distance of 50 feet is to be carefully dressed and given a gentle slope outwards of 1 in 40.

Mortar.

1. **Lime.**—Limestone or kankar must be burned with coal, charcoal or wood, and not with *uplas* (cowdung cakes). A design for a kiln is given in *Plate* XX.

2. Lime must be delivered at the site of the mortar mill quite fresh, i.e., within seven days of the date on which it was burned; it must be entirely free from ashes, under-burned particles, and other impurities.

3. Lime may be either slaked, or ground fine in properly made mills as shown in *Plate* XXI, according to the custom in the district in which the manufacture is being prosecuted, or as may be directed by the A. C. R. E., but it must always have been passed through a sieve of 64 meshes to the square inch, before it is put in the trough for mixing.

When it is stored it must be preserved perfectly dry. If it is necessary to store fat lime for any time, it should be kept in an enclosed place in a large heap and the air excluded in every way possible, or it may be kept for many weeks in tanks if covered with water.

4 **Surkhi** must always be made of burned bricks or clay (free from over or under burnt particles) by grinding or pounding, and if for use with fat limes must be ground as fine as possible and screened. It must be perfectly clean and free from any admixture of foreign matter.

5 **Sand or Budjri.**—Sand must be sharp, clean, coarse river sand, free from all admixture of earth or other impurities, to effect which, it must be washed when necessary. If necessary, it should also be screened to remove pebbles, &c.

6 **Mixing.**—Mortar will be composed of lime and surkhi or sand in various proportions according to the nature of the lime used, to be fixed by experiment at each station and approved by the C. R. E.

7 All mortar will be mixed by measure, not by the weight of the ingredients, which will be ground together in the mill as before described, until they are thoroughly incorporated, care being taken that too much water is not used in the operation. The grinding must continue for four hours at least before the mortar can be considered fit for use.

8 Mortar which has once set, or which has lain for more than 24 hours after it has been ground, must on no account be used in any work. When using kankar lime for plastering it is, however, better to leave it for some time to sour.

9 Mortar should be kept ready for use in the narrow troughs shown in *Plate* XXI, and in hot weather it should be covered with matting or thatch to prevent its drying or setting too quickly from excessive heat.

Concrete.

1 **Ingredients.**—Concrete is to be composed of the ingredients found by experiment at each station to be most suitable, and approved by the C. R. E.

2 **Mortar.**—The mortar for concrete will be prepared as described above. It must then be thoroughly incorporated with the broken brick, broken stone, or gravel, (as the case may be,) or prepared as may be specially directed.

The proportion of mixed mortar to be used will be ascertained as follows:—an iron tank or other suitable vessel of known capacity will

be filled with the ballast to be used which will be struck level with the top of the vessel. The vessel will then be filled with water, and kept full until the ballast ceases to absorb it. The water will then be drawn off and its cubic contents ascertained. By adding 10 per cent to this, the actual quantity of mortar to be used for the amount of ballast in the tank will be ascertained.

3. **Ballast**.—The broken stone, broken brick, or gravel, must be perfectly clean and free from all impurities before being mixed with the mortar, and must have been soaked in water for at least four hours previous to mixing.

4. For the mixing of the concrete, a special broad shallow platform of sufficient size to give ample room for mixing from 8 to 10 cubic feet must be built. This platform should be floored with brick, flagging or wood so as to keep the materials clean and pure.

5. Broken brick must be thoroughly well burned, and no individual piece either of this material, of gravel, or of broken stone, which is intended for use in concrete, should exceed in size what will pass, in any direction, through a ring 1½ inches in diameter. Smaller pieces may be used, however, with advantage, down to those which will pass through a ring half an inch in diameter.

6. **Laying**.—The concrete must always be used while quite fresh. It must be *laid* (not *thrown*) in the trenches, or in any position in which it may be desired to place it.

7. Concrete should be laid in courses, each course being as nearly 6 inches in thickness, as the convenience of construction will allow. Each course is to be well rammed and consolidated before the next is laid.

8. No concrete is to be laid after 2 p.m., this is to ensure its being properly consolidated before nightfall. Ramming next day after the mortar has had time to set should be prohibited.

9. Concrete must not be laid of too fluid a consistency; after it has been mixed no more water should be added, the surface during and after consolidation must however be kept damp for at least seven days.

10. Iron rammers, not weighing less than 12 lbs., should be used, and the ramming should continue until the lime has partially set, or until a walking stick, when dropped endways upon it from a height, will rebound from the surface; with brick ballast wooden rammers may be used.

11 In laying consecutive layers of concrete, the lower course should be clean and well watered before the upper is laid, and, where it is necessary to make joints in layers, they should be arranged as shown in the margin

12 **Portland Cement Concrete.***—The concrete may be mixed in varying proportions of cement to sand and ballast, according to its position in the work

When in any specification a certain proportion of cement is laid down, *e g*, Portland cement concrete 6 to 1, it is intended that 1 part of cement should be mixed with 6 parts of ballast and sand previously mixed together, the proportion of sand being so regulated that together with the cement it completely fills the interstices in the ballast In large walls or heavy foundations 25 cubic feet of large stones may be added to 100 cubic feet of the cement concrete, mixed as above

13 Cement should be up to the British Standard Specification It should be laid out on a floor for a few days under cover, in order to get rid of any heat, which would cause it to blow or swell in setting If exposed thus in dry weather for some time, up to three weeks, it increases in both strength and bulk

14 Cement concrete will be mixed and laid as specified above, but the following additional precautions must be taken —

The ballast after having been well soaked should be allowed to dry externally and be mixed first in small quantities with sand and cement previously mixed together dry Water should not be added until just before it is intended to lay the concrete, it should be poured on gently through the rose of a watering pot, care being taken that the mass is not allowed to become too fluid in consistency It should be laid as soon as mixed, and all ramming necessary must be done on the day it is laid On the following day it should be covered with water and kept so for 14 days In places where this cannot be done wet sand is to be used instead of water

* For further particulars regarding Portland cement concrete in submerged works see D G M W Circular No 7B of 9th May 1893

15 *Proportions of Mortar and Ballast for Concrete*

	Mortar	Ballast
For layers of 6 in thickness and over	30	100
" of less than 6 in thickness	35	100
" terraced floors and roofs	50	100

Brickwork.

1 **Description of Brickwork** —First class brickwork will consist of stock made bricks of uniform colour and shape thoroughly well burned, and of a deep red or copper colour Each brick must be square and well shaped must ring clearly when struck, and must be perfectly sound in all respects It should not absorb more than $\frac{1}{15}$th of its weight when soaked 12 hours in water

2 Second class brickwork will consist of bricks which are thoroughly burnt, sound, and well shaped They will be the same as first class bricks, with the exception that the colour need not be quite so high, or uniform throughout the structure The inner bricks may be of a lighter colour, but for all face work bricks should be selected for uniformity of colour

3 There will be no difference whatever between first and second class brickwork, either in the mortar used in the method of laying, or in the bond

4 First and second class brickwork will be built as indicated on the plans, as specified by the A C R E in his estimate, or as directed by that officer on the works, and at the rates agreed to in the contract bond

5 **Bond, &c** —The bond to be used in all brickwork will be "English," see *Plates* XI and XII, and no half bricks or brick bats will be allowed to be used except when necessary to complete the bond

6 In building arches, concentric rings are not to be used, but each course of the arch must be regularly and systematically bonded see *Plate* XIII

7 All bricks in each course of an arch must be regularly and carefully summered to the radius of the arch, and this, when practicable,

should be effected by moulding and burning the bricks specially for the work, in cases where the amount of arch work to be done is small, the summering may be effected by cutting or grinding

8 **Mortar.**—The mortar to be used will be as specified on pages 2 and 3

9 **Laying** - Care must be taken that each course of bricks laid is quite level and perfect in bond, and that each brick is well bedded and flushed in sound mortar

10 No joints or beds are to exceed three eighths of an inch in thickness, and those in arches should not exceed one-quarter of an inch

11 In the face of a wall every five bricks must cover 3 feet $10\frac{1}{2}$ inches in length, when the bricks measure $9'' \times 4\frac{1}{2}'' \times 2\frac{3}{4}''$, and no four courses, including three joints, shall gauge in height more than 1 inch in addition to the thickness of the bricks themselves

12 Walls are always to be carried up as level as possible along their entire length and no step left temporarily during construction, never to exceed eight courses in depth

13 When brickwork in one section of a building cannot be carried up in level courses, the work must be raked back in regular steps (one course each) so that the new work to be added may be built on over the old

14 Care must be taken to ensure all iron or stone fixtures, perforated jamb bricks, &c, being built into the work as it proceeds, in the position shown in the drawings, or as directed by the A C R E

15 The space between a relieving arch and a flat arch or lintel should not be filled in until the building is completed, unless it is found to be absolutely necessary to do so

Centerings are to be struck within 24 hours of the completion of a segmental arch, but in case of semi circular, semi elliptical or pointed arches, not until the adjacent brick work has reached two thirds of the height of the arch

16 **Damp Proof Course**—On damp sites a damp proof course should be given, such as a course of slate in cement, a layer of asphalte or fine cement concrete The concrete floor in some cases may be carried through the walls as a damp proof course In magazines, &c, damp may be prevented by building the walls hollow

17 **Watering** —Care must be taken that walls, as they progress, are kept thoroughly well watered on their faces and tops, and, when work is left off at night, a fillet of mortar about 1½ inches high should be made round the edge of the last course laid, so as to form a trough, which should be filled with water before the workmen leave off work for the day

18 No brick ■ to be used unless it has been thoroughly soaked in water for at least two hours

19 Garden shaped watering pots should be used for wetting brick work, the upper half only of the rose being perforated

20 Where new and old brickwork are to be connected together, the old work must be well wetted and saturated with water for two days previous to the new work being commenced

21 All new work when built must be kept watered and damp for at least seven days

22 **Brickwork in clay** —Walls will be built of bricks laid in clay when ordered or specified. This work will be as specified for brickwork in mortar with the following exceptions —

(a) The cementing material will be well tempered clay instead of mortar

(b) The top courses of unfinished work need not be kept covered with water

23 The mud mortar is to be made of stiff white or red clay according to locality, which is to be broken up into a fine powder and freed from stones, or other impurities It is first mixed with water on a brick or wooden platform and well worked up with the feet to the consistency of clay for brick making. It is then to be gradually thinned with water until it assumes the consistency of stiff mortar when it will be ready for use

24 **Sun-dried Bricks in clay mortar** —Slop moulded bricks are generally used, and joints may be thicker than for burnt brick work

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Stone Masonry.

1 **General** —The masonry to be used will be *Ashlar work, Coursed rubble, Random squared coursed rubble, Random coursed rubble, Random uncoursed rubble, or Dry rubble* as may be specified

2 In foundations a cheaper specification may generally be adopted than for superstructure.

3 The stone to be used will be that taken from the quarries mentioned by the A C. R. E. in his specification, or as may be directed It will be hard, durable, and tough, and each stone must be laid when in the work, on its natural quarry bed, all stones will be soaked in water for at least four hours before being put into the work

4 The mortar to be used will be as specified for brickwork

5 All masonry should be kept well watered in the same manner as is laid down for brickwork for at least seven days.

6 **Ashlar work.**—Generally speaking, for all ashlar work, the A C R E. will supply the Contractor with the exact dimensions of each stone, or with a plan of each course of masonry showing the necessary dimensions

7 Ashlar work will have its beds and joints finely dressed, free from any winding, and true and square in every respect.

8 All joints and beds will be perfectly vertical and horizontal respectively; they will never exceed ¼ inch in width or depth, and each stone will be well set and flushed up in mortar, as laid down under that head on pages 2 and 3

9 All joints and beds of ashlar work will be constructed, as laid down in para. 8, but the outer face or faces may be *rock faced, finely chisel-dressed, rock faced with chisel margin, rock faced with chisel margin and chamfered edge*, or as may be described by the A. C R E. either in his specification, or on the ground

10 Ashlar work shall never be laid in courses of less than 10 inches in height, no stone should be of less volume than 1½ cubic feet, one-fifth of the face should be headers, and no stone should have a less width of bed than 1½ times its height

11 When ashlar quoins or ring stones are provided, the arrises must be dressed clean, sharp, true, and free from all winding, in the former quite plumb and vertical, and in the latter lying exactly in the line of the perimeter of the circle indicated or directed

12 **Coursed rubble.**—Coursed rubble will be laid in courses varying in height as may be most convenient and economical, according to the nature of the stone procured from the quarry, as regards either

the depth of the natural beds of the stone, or the manner in which it will cleave, but no course will ever be less than 4½ inches, or more than 9 inches in thickness

13 Coursed rubble may have its courses either of equal or of unequal height, but in the latter instance, the deeper courses must be laid towards the bottom of the structure, and may gradually get shallower within the limit given above, as the wall progresses in height

14 Buildings constructed with coursed rubble masonry may be supplied with ashlar quoins of the height of one or two courses and care should be taken, when equal courses are specified, that the height of the wall is divided into an exact number of courses, and an exact number of quoins.

15 All beds and joints must be perfectly true, both horizontally and vertically *throughout*, and well flushed with mortar *They must never be* more than half an inch in width or depth respectively, the line of each course must be perfectly level and free from winding, and no joint must overlie another less than 4½ inches, measured on the face of the wall

16 No stone should be used which is less than half a cubic foot in size, its bed must never be less than 1½ times its height, and care must be taken that the interior of the wall is carefully constructed with proper sized stones set in mortar and not filled up with spalls and chips

17 In each course there should be a bond stone at every five feet, and in walls of 2½ feet thick or under, the bond stone must be one stone In thicker walls two stones overlapping at least 9 inches may be used for bond

18 **Random square coursed rubble**—This description of masonry will be coursed every 18 inches in height, and will have quoins of equal or unequal height, but every two quoins must equal the height of a single course—*see Plate* XVIII

19 Each course will be made up of unequally sized stones, dressed perfectly square and true to whatever size is possible from its dimension as it comes from the quarry

20 Two stones may have their joints immediately over another, but the third stone should always overlap at least 3½ inches One-fifth of the face of the wall should consist of through headers All other stones should be in half bond, or should overlap each other at least one-third the thickness of the wall.

21. All joints and beds must be perfectly vertical and horizontal respectively, and must never exceed half an inch in width or thickness throughout.

22 No stone must be laid whose bed is not at least 1½ times its height, and the work may be roughly punched, each stone being well flushed in mortar.

23 **Random coursed rubble**—For this description of masonry *see Plate* XVIII : Each stone will be punched in to the number of sides to which it can be most conveniently dressed, and will be then so fitted into the wall that the joints shall never exceed half an inch throughout The vertical joints of each course must break joint at least 3 inches with those of the courses above and below it, and no face stone is on any account to be narrower or shorter than its height. *If it be of irregular shape its length at right angles to the face of the wall must be at least* 1½ times its height

24 Random coursed rubble masonry should be supplied with equal or unequal quoins, and should be coursed every 18 inches, one fifth of the face should be through headers, and no stone should be less in depth than 1½ times its height, every stone being well flushed in mortar as described for masonry under other heads

25 All stones which are not headers shall half bond or overlap with one another, at least one-third the thickness of the wall, and the quoins may be either of equal or of unequal height, but there must always be two quoins to every 18 inches of wall in height

26 **Random uncoursed rubble**—The stones will be laid at random without being brought up to any level courses, each stone will be laid on its quarry bed, will be bedded in an ample supply of mortar, and will be wedged or pinned strongly into its position in the wall by spalls or chippings, which may show on the face

27 No fixed rule can be laid down for sizes of joints, but they must be kept as small as possible This work is subject to the same rules for through or bond stones, as specified above for other classes of rubble masonry

28 River boulders and large pebbles may be used for this sort of work, either laid in their natural forms, or split, and their fractured surfaces shown on the face of the work

29 When walls are built of this material, bands of brickwork, or masonry of a more regular description, should, at fixed vertical intervals,

the depth of the natural beds of the stone, or the manner in which it will cleave, but no course will ever be less than 4½ inches, or more than 9 inches in thickness

13 Coursed rubble may have its courses either of equal or of unequal height, but in the latter instance, the deeper courses must be laid towards the bottom of the structure, and may gradually get shallower within the limit given above, as the wall progresses in height

14 Buildings constructed with coursed rubble masonry may be supplied with ashlar quoins of the height of one or two courses, and care should be taken, when equal courses are specified, that the height of the wall is divided into an exact number of courses, and an exact number of quoins

15 All beds and joints must be perfectly true, both horizontally and vertically throughout, and well flushed with mortar They must never be more than half an inch in width or depth respectively, the line of each course must be perfectly level and free from winding, and no joint must overlie another less than 4½ inches, measured on the face of the wall

16 No stone should be used which is less than half a cubic foot in size, its bed must never be less than 1½ times its height and care must be taken that the interior of the wall is carefully constructed with proper sized stones set in mortar and not filled up with spalls and chips

17 In each course there should be a bond stone at every five feet, and in walls of 2½ feet thick or under, the bond stone must be one stone In thicker walls two stones overlapping at least 9 inches may be used for bond

18 **Random square coursed rubble** —This description of masonry will be coursed every 18 inches in height, and will have quoins of equal or unequal height but every two quoins must equal the height of a single course—*see Plate* XVIII

19 Each course will be made up of unequally sized stones, dressed perfectly square and true to whatever size is possible from its dimension as it comes from the quarry

20 Two stones may have their joints immediately over another, but the third stone should always overlap at least 3½ inches. One-fifth of the face of the wall should consist of through headers All other stones should be in half bond, or should overlap each other at least one-third the thickness of the wall

21. All joints and beds must be perfectly vertical and horizontal respectively, and must never exceed half an inch in width or thickness throughout.

22 No stone must be laid whose bed is not at least 1½ times its height, and the work may be roughly punched, each stone being well flushed in mortar.

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24 Random coursed rubble masonry should be supplied with equal or unequal quoins, and should be coursed every 18 inches, one fifth of the face should be through headers, and no stone should be less in depth than 1½ times its height, every stone being well flushed in mortar as described for masonry under other heads

25 All stones which are not headers shall half bond or overlap with one another, at least one-third the thickness of the wall, and the quoins may be either of equal or of unequal height, but there must always be two quoins to every 18 inches of wall in height

26 **Random uncoursed rubble.**—The stones will be laid at random without being brought up to any level courses, each stone will be laid on its quarry bed, will be bedded in an ample supply of mortar, and will be wedged or pinned strongly into its position in the wall by spalls or chippings, which may show on the face

27 No fixed rule can be laid down for sizes of joints, but they must be kept as small as possible This work is subject to the same rules for through or bond stones, as specified above for other classes of rubble masonry

28 River boulders and large pebbles may be used for this sort of work, either laid in their natural forms, or split, and their fractured surfaces shown on the face of the work

29 When walls are built of this material, bands of brickwork, or masonry of a more regular description, should, at fixed vertical intervals,

run through the whole thickness of the wall, to assist in tying it all together

30 **Masonry in clay.**—When any of the above kinds of stone masonry is specified to be laid in clay it will be carried out as specified for mortar, except that—

(a) The cementing material will be well tempered clay instead of mortar

(b) The stone used need not be soaked previous to use.

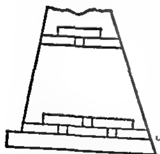
(c) The top course of unfinished work need not be covered with water

31 The clay will be prepared as specified under Brickwork, para. 23

32 **Dry rubble.**—All the above kinds of masonry can be carried out dry, that is without the use of mortar This sort of work is in very general use for breast and retaining walls in hill roads

33 In these cases the front batter should never be less than ⅙ The back slope should be about ⅙ The coursing will always be normal to the front face of the wall, and there will always be a projection or broad footing at the base. The top of the wall must not be less than 2 feet thick. In surcharged walls this thickness must be increased to 3 feet.

34 Through bond, from front to back, consisting of a single stone or of several stones put together, must be given in every course at every 5 feet along the face of the wall Where bond stones of length equal to the thickness of the wall are procurable, they are always to be used



35 In thicknesses beyond this limit the through bond will be given as shown in marginal sketch. Care must be taken that the spanners bear normally on the other stones, so that with the superincumbent weight, they may act truly as binders.

36 The limit of height for such walls will depend on the quality of the stone, and on the space available at the base. Unless the stone be very good, and other circumstances be favourable, they should not exceed 12 feet in height, after which mortar should be used.

37. The filling immediately behind the wall should consist of stone refuse and chips. Earth is not to be used if it can be avoided

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Pointing.

1. If masonry is to be pointed or plastered the joints should be raked out to a depth of half an inch as the work proceeds, no pointing is to be commenced until the raking out has been seen and passed by the officer in charge of the work.

2 The face of the walls to be pointed must be kept thoroughly wet for two days until the pointing is commenced

3 Mortar for pointing should be specially ground until there are no lumps or grit in it.

4 The joints and bed lines of each course on the face of the wall will then be covered over with a thin coat of mortar, care being taken that the pointing is not allowed to spread over the stones or bricks, but that it is confined only to the outer surface of the joints and beds, the mortar forming the pointing should not be allowed to project from the face of the wall

5 As soon as the pointing is made to adhere to the original mortar, the centre of the lines of the beds and joints may be marked with the edge of a trowel, or by pressing a plumb line into the soft putty, and care should be taken that all these lines are true, square, and parallel or the pointing may be struck back with a trowel along the upper edge of the joint (see sketch)



6 After the pointing shall have been completed, it should be kept damp for two or three days

7 **Cement pointing.**—This will be carried out in the same manner as lime pointing, except that instead of lime mortar equal parts of pure Portland cement and fine sand will be used, greater attention will be paid to thoroughly wetting the wall before the pointing is applied, and the wall must be kept wet for at least seven days after the pointing has been completed

Plaster.

1 Plaster will be composed of the ingredients laid down for each District and will be laid in one, two, or three coats, as may be found necessary

2 Brickwork will never have more than one coat of plaster, but masonry may have three, and no single coat shall ever exceed half an inch in thickness

3 Previous to the application of the plaster, the joints of the brick work or masonry must have been raked out to a depth of at least half an inch, and this is best done as the work progresses in construction, and while the mortar is still green No plastering will be commenced until the raking out has been seen and passed by the officer in charge of the work

4 **Rough casting.**—After the joints shall have been raked out, the wall must be cleaned down and kept thoroughly damp for two days until the plastering is commenced

5 The plaster may then be applied, and, before each coat sets, it must be well beaten with long thin laths, (to consolidate and compress the mortar,) until such beating makes no impression on the surface

6 When two or three coats are ordered, the first must be allowed to set completely before the second is laid, and the surface should be left rough, and freely scored all over with the edge of a trowel, to prepare it for the next coat

7 If it be thought desirable, the plaster may, during the process of beating, be well sprinkled with a mixture of 3½ seers of *gur* (coarse sugar) dissolved in 20 to 30 gallons of water, to which may be added 2 seers of bael fruit (wood apple), this will quicken the setting of the mortar and improve the quality of the plaster

8 **Floating** —After the "rough cast" has been applied as above in the number of coats directed or specified, and has become quite firm, the next operation will be "floating," which will be done with a long straight-edge called a float

9 A sufficient quantity of fine plaster should be thrown on the wall, so as to allow of its being brought to a completely smooth surface, by drawing over it the plasterer's float backwards and forwards

10 **Rendering or setting coat**—As soon as the surface is perfectly true and level, and quite dry and set, it will be "rendered" quite smooth by having lime putty spread over it with the face of a large trowel, with which it must be rubbed in until it becomes perfectly smooth and even The plaster must then be kept thoroughly wet for at least 10 days.

11 In order to guard against the setting coat showing numberless fine cracks all over its surface, as frequently happens from the unequal shrinking of the different coats, it should not be applied till the previous coat is quite dry, otherwise, being very thin, it will harden from exposure to the air before that previously laid has done shrinking, the result being that, if there is a proper adherence between the two coats the setting coat will be disfigured by numberless fine cracks, whilst where the coats have not adhered well together, hollows will be found and the setting coat will be liable to come off at those spots.

12 If the plaster is to be whitewashed this is not to be commenced until the plaster has been examined and passed by the officer in charge of the work

13 **Mud Plaster**—Mud plaster will be composed of stiff clay and chopped straw in the plains and of stiff clay and pine spines in the hills in equal proportions in bulk The clay after being excavated is to be spread out to be scorched by the sun It is then to be reduced to powder and stacked in heaps of 100 cubic feet or as required

14 The straw or pine spines will then be thrown over the clay and mixed with phowrahs in a dry state till thoroughly incorporated Water is then to be added, and the whole left for two days to soak It will then be mixed with the feet and phowrahs, water being added as required till it assumes the consistency of stiff mortar

15 It will then be spread evenly over walls or roof with the hand or trowel to the thickness of 1 inch on roofs and ½ to ¾ inch on walls, and be floated to an even surface with a straight-edge about 3 feet long The plaster will then be allowed to dry, and the cracks that open out during the process of drying will be filled in with liquid cow-dung With some clays sand may be added with advantage

16 **Leeping.**—The surface will then be leeped over with a mixture of cow-dung and clay This will be done by hand on roofs, and by

trowel and float on walls Care will be taken to preserve all lines, mouldings, &c, that existed previously

17 The cow-dung is prepared by first steeping it in water to free it from grass, straw and other impurities, then one cubic foot of finely powdered clay is added to one cubic foot of cow-dung, and both ingredients are mixed in a tub and thoroughly worked up together

18 **Cement Plaster** —The walls will be prepared as for lime plaster, and rendered with half to one inch coat (as specified) of 1 part of Portland cement to 3 parts fine sand and the surface left rough but will not be beaten A thin coat of $\frac{1}{8}$ inch pure Portland cement or equal parts of cement and sand will then be floated over the surface and well polished with a trowel or flat board The cement should be used within one hour of mixing and the surface kept wet for at least 15 days *after plastering has been completed*

Whitewash.

1 **Preparation of walls** —The walls will be thoroughly cleaned down and freed from all foreign matter before the whitewash is applied

2 In special cases when it is considered necessary to remove the old whitewash, or to scrape the walls, this work must be separately specified

3 **Wash** —The wash will be prepared from shell lime when available, otherwise from fresh stone lime slaked on the spot.

4 The slaked lime will be placed in tubs nearly full of water, and will then be mixed and stirred up until it attains about the consistency of thin cream

5 When sufficiently mixed, the wash will be taken out in small quantities and strained through a coarse cloth into *ghurrahs* (earthen pots)

6 Gum in the proportion of 2 chittacks to one cubic foot of lime will be added to the strained whitewash, and the whole will then be boiled together

7 Whitewash will be laid on in three coats with a brush, the coats being laid on vertically and horizontally alternately, and each coat is to be allowed to dry before the next is applied.

8 This specification will apply to all colour washing, the only difference being that the colour specified or directed will be obtained by adding the necessary colouring matter to the strained whitewash

9 In re-colour washing walls, a coat of whitewash will first be applied over the old colour wash to kill the former colour, when dry the new coat of colour wash will be added Care must be taken that the workmen keep the mixture constantly stirred while putting it on, otherwise the colouring matter will settle, and the work be uneven and streaky

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Floors.

1 **Floors in lower stories—Preparation of surface.**—The plinth filling shall first be watered and rammed until it is completely consolidated, and will not yield to a heavy blow with an iron road metal rammer

2 When the above operation is completed a sufficient quantity of the filling will be removed, so as to make room for the flooring to be placed at exactly the height and position indicated on the plans

3 For inner floors the excavations will be perfectly level, but in all verandahs it will be so executed as to ensure an outward slope of 1 in 40 to the flooring when completed

4 **Brick flat flooring**—This will consist of 1st class pressed bricks carefully selected, unless otherwise specified laid on 3 inches of concrete

5 As soon as the plinth filling is cleared out as above described, a concrete bed of 3 inches in thickness will be laid as specified under the head of ' Concrete

6 Care must be taken that the concrete is kept perfectly level where it is so indicated on the plans, and that the proper slopes, where such are indicated, are uniformly and evenly carried out and the concrete will be kept wet until set

7 The concrete bed must be inspected and passed by the officer in charge of the work before any bricks are laid

8 The bricks will be laid on this concrete, being bedded thereon in lime mortar The joints between the bricks are not to exceed $\frac{1}{16}$ inch in thickness, the sides of the bricks being rubbed if necessary to give

this joint Care must be taken that the sides are worked square with the face of the brick and not tapering downwards to give a false fine joint on top

8 For all brick flooring, the bricks are to be soaked in water for four hours before being used, and adjacent courses are to break joint. The floor must be kept wet for seven days after laying

10 **Brick on edge flooring.**—This will be constructed as specified for brick flat flooring except that the bricks will be on edge

11 **Tiled brick flooring.**—This will consist of 1st class machine pressed tiles made of tile clay They will be laid as specified for brick flat flooring

12 **Terraced flooring.**—The preparation of the plinth will be done as specified for brick flat flooring The terraced flooring will, unless otherwise specified, be 6 inches thick and be laid as follows —

13 The concrete will be composed of broken stone or broken *kangah* (over burned) brick, the largest pieces of which will be capable of passing whichever way they are turned, through a ring one inch in diameter This ballast will be steeped in water for four hours before being mixed with the mortar

14 For proportion of mortar to ballast see "Concrete," para. 15

15 When the concrete is thoroughly mixed, it will be laid in a thickness of 6 inches deep Care should be taken that the concrete is not in too fluid a state When laid it will be beaten with small round rammers 6 inches in diameter until it shall have been reduced to 5 inches in thickness, and until the mortar shall have partially set While this operation is under progress, the surface should be frequently tested and kept perfectly true and even

16 While the beating is going on, the surface of the concrete will be liberally sprinkled with water, in which *gur* (coarse sugar) and bael fruit (wood apple) are dissolved in the following proportions, viz, 3½ seers *gur* and 2 seers of bael fruit to 20 to 30 gallons of water

17 As soon as the beating shall have been completed as described, the surface will be softened by being sprinkled with pure water, and the mortar, which has been brought to the surface by the beating, will then be smoothed, and rendered with the face of a trowel

18 The surface should be worked to a very fine polish, and to assist this, fine lime putty may be used sparingly (the less the better), and as

the process advances, the surface should be liberally sprinkled with water in which bael fruit and gur are dissolved in the proportions mentioned in para. 16

19 No plaster is to be laid over the concrete on any account, as this, though a common practice, is often the source of great evil afterwards The fine polished surface which it is advisable to give to the concrete, in order to prevent the floor breaking up speedily, will be given as already described, by rendering the mortar brought to the surface perfectly smooth with the face of a trowel, and by means of lime putty sparingly used

20 As soon as the upper surface of the floor shall have been rendered thoroughly smooth, and a fine polish given to it by the free use of the smooth surface of a trowel, it will be covered with 2 inches of fine sand or grass, which will be kept damp for 21 days

21 **Flagged flooring** —This will consist of the best stone locally procurable as may be specified laid on rammed earth and concrete, as specified for brick flat flooring

22 As soon as the concrete shall have completely set, the laying of the flagging may be commenced The flags may be of unequal sizes, but must be hard, even, sound and durable

23 The flags will be between $1\frac{1}{4}$ and $1\frac{3}{4}$ inches in thickness, never less than 14 inches wide, or greater in length than 2 feet 6 inches They will be dressed true and square, both on their upper surfaces, and also on the faces of their edges, to which latter on no account must a wedge shape be given Each flag will be soaked in water before laying in mortar

24 The flags shall be set in an abundance of mortar, as specified for brickwork and well tapped down with a wooden mallet They shall be laid in courses parallel to the shorter wall of the room and each course must be of uniform width

25 No joint shall exceed $\frac{1}{16}$ of an inch in width throughout, and they shall all be perfectly square, level and true with each other, no one projecting over another, and no cross joints in two adjacent courses shall be less than 8 inches apart

26 The flagging must be kept well watered for seven days after the completion of the laying, and no dressing is to be allowed after the flooring is laid

27 Cement concrete over lime concrete flooring.— The floor to consist of 1 inch or ¾ inch pure cement concrete over 4 inches or 4½ inches of ordinary lime concrete

28 In laying in such places as verandahs brick or stone edging must be given, against which the concrete can be rammed The offset of the plinth and the brickwork under the doorways must not be carried too high to allow of the full thickness of the lime concrete going over it as the cement concrete will not amalgamate with the brickwork, if laid on it

29 Care must be taken that the filling under the lime concrete is thoroughly consolidated or the whole floor will crack The lime concrete is laid in the ordinary way, and thoroughly rammed, care being taken that the surface is true to level, or to the slope required for the floor, so that the thickness of the cement concrete may be uniform

30 The ballast for the cement concrete is hard stone, broken so that the largest pieces are not larger than ½ inch cubes, but much of it must be much smaller than this, part of it should be as fine as large shot This ballast must be kept well wetted for 12 hours before use if this is done by soaking it must be drained before being mixed with cement

31 The cement part of the work is best done by daily labour, to ensure careful work

32 With ten parts of this ballast four parts of pure Portland cement are mixed The greatest care must be taken that only enough water is used to cause the cement to become a *thick* paste Making it sloppy, as native masons like to do, will spoil the work

33 It must be mixed in very small quantities (about ½ cubic foot) the water being supplied from a rose

34 The lime concrete must not be allowed to set before the cement concrete is laid, this is of the greatest importance as the essential principle of the floor is that the two concretes should combine, so that a section would show shading from one to the other, and not a distinct line

35 The surface of the lime concrete should be thoroughly clean, and should be moistened before laying the cement concrete

36 When all is ready the cement concrete will be thoroughly mixed and evenly spread (using a straight edge to ensure this) and *at once* well beaten with 5 lb wooden "thappies Different men must be

employed on each of these operations, so as to keep the operations continuous. As many men should be employed beating as there is room for, the labour costs little compared to the cement, and it is very important that the consolidation should be quickly carried out.

37. It should be beaten until the cream comes to the surface; this should be in less than 15 minutes from the time of commencing the mixing. It must be remembered that cement sets quickly, and preventing it doing so, by continuing to beat it, spoils the work.

38. If the cement does not come to the surface readily, a little dry cement may be scattered over the surface; but if it seems necessary to add more than a very little, the concrete should be dug up and dry cement added, and a little water sprinkled over it. Anything in the least nature of plastering, or even rendering, spoils the work.

39. When the cream comes to the surface, if it is too thin, part should be wiped off, and a little dry cement scattered over the surface.

40. When the cream has come to the surface, the floor should be floated over; the men engaged on this should sit on small boards on the new floor if they cannot reach the work from outside it.

41. After smoothing the floor must be kept thoroughly wet until the cracks are filled in—*vide* from para. 47—and for seven days afterwards and the floor should not if possible be taken into use for about a month after laying, though in a fortnight it will be fairly good. Sand or grass is generally put over it to protect it, and is kept soaked with water, but neither of those must be put on until the floor is hard enough not to be marked by them.

42. The only way in which this floor has been found to fail is cracking from contraction, where there is a continuous floor of greater extent than 10 or 12 feet. To prevent this either of the following methods of laying will be found successful.

43. **1st Method**.—The floor is divided into sections 6 or 8 feet long, by pieces of flat iron $1\frac{1}{4} \times \frac{3}{16}$, these are well oiled before being put in the work, and are taken out the morning after the cement concrete has been laid. After three days the interstices thus left between the different sections of the floor are filled in with asphalte, or some similar substance; they have frequently been filled in with cement, but this is liable to crack down the joint, though not nearly so much so as if the floor had not been laid in sections, and the cracks are easily

repaired Paper might perhaps be used, as described in paragraph 50 The difficulty in this method of laying is the removal of the iron strips, without disturbing the concrete, but a very large number of floors have been laid on this system

44 **2nd Method** —The following method has been used at Rawalpindi, with great success It is, however a good deal more troublesome than the first method

45 On the lime concrete foundation wooden screeding will be laid dividing the whole space to be floored into squares about 8 × 8, the screeds are to be prepared and laid by carpenters, they are to be slightly tapered and wrought on sides and top

46 The top surface of the screeding is to be in the plane of the surface of the Portland cement concrete floor

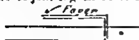
The size of the squares should not exceed 12 × 12 as a larger square than this would crack under variations of temperature In starting this class of work for the first time it is recommended that small squares only 4 × 4 be attempted, when the men employed are proficient at working level for small squares, larger squares can be progressively tried

47 The depth of the screeds depends of course on the thickness of the floor, their thickness is immaterial so long as it is sufficient to withstand bending during the laying of the concrete

48 The concrete will be laid successively in squares 1, 3, 5, 7, 15, 17, 19, 21, *vide* marginal sketch

49 As soon as the cement creams up it will be floated off flush with the top surface of the screeding

50 After one clear day has elapsed, in the case of each square, the screeds aa, aa, bb, bb, etc, will be removed (AA and BB being left in) and concrete laid in squares 2, 4, 6, 16, 18, 20 On no account must attempt be made to join together any two adjacent squares and to prevent this being done, thin paper must be placed in the joints as shown in the marginal sketch



51 The squares mentioned in the preceding para having been completed, screeds AA, BB should be removed (but bb—bb being left in), the remaining portion of the floor should then be dealt with in a similar manner The object of the screeding can now be explained it is firstly to secure truth of surface, secondly to prevent ramming in a desultory way over the whole floor and thereby doing much damage, thirdly to leave joints in the concrete thereby preventing cracks

52 If it is desired to polish, after three clear days after the concrete in each square has been laid this will be done by rubbing with a hard stone, sand being freely used The polishing is to be continued until the cement has been rubbed down to show the stone aggregate

53 Bricklayers have a strong tendency to plaster concrete, the polishing will exhibit this malpractice if it has occurred and by rendering its exposure certain thereby check it Beyond checking the habit of plastering, there is no particular object in polishing

54 If it is not intended to polish the surface should be finished off by floating off the cement which has creamed up to the surface under ramming

55 An ornamental floor can be produced suitable for churches by laying all the concrete with the screeds *in situ*, these should be taken out in due course and the space they occupied filled in with concrete made with marble chippings or with the cement coloured with indigo, cochineal, lamp black, &c

56 **Asphalte flooring**—Will be laid on a concrete bed which must be perfectly level, dry, and free from dust or dirt before the asphalte is laid

57 The asphalte is usually imported in blocks, known as mastic, in which the natural asphalte has been mixed with sand and bitumen Val de Travers and Seyssel's Asphalte are the best known brands

58 The following proportion will be used —

Asphalte (mastic)	1 part
Bitumen	$\frac{1}{32}$ part
Coarse sharp sand or fine grit	25 to 40 per cent of mastic by weight.

59 The sand or grit must be quite free from dust, clean and dry, and screened through two screens It should pass through a sieve of 12 meshes, but not through one of 18 meshes to the lineal inch

60 To mix the asphalte, first lay in the bottom of the caldron about ¼ of the bitumen to be used, and heat over a wood fire. When this is dissolved, one third fill the caldron with pieces of mastic of not more than about 5 lbs each. As the mastic softens and melts it must be well stirred and more pieces added until the caldron is nearly full, adding ½ of the bitumen gradually. When the whole is well melted and thoroughly stirred the sand or grit will be added gradually and the whole stirred until the grit is well incorporated with the mastic; the rest of the bitumen (¼) will then be added. The mixture is ready for use when small jets of steam are being given off and when it will fall freely from the stirrer. None of the composition should adhere to a clean cold iron rod when dipped into it.

61 Strict supervision is required in mixing to prevent too large a proportion of the bitumen being added. Workmen are tempted to do this as the asphalte when so mixed is laid with greater ease than when the proper proportions are used. In hot climates the smallest possible quantity of bitumen which will enable the men to work the material will be added.

62 When the preparation is ready for use, the boiling mixture is to be taken from the caldron with an iron ladle and laid on in rectangles 3 × 2 between wooden gauges, and spread evenly with a hot trowel to the requisite thickness. After one piece is spread the surface is to be sprinkled with clean sand, and rubbed smooth with a hard wood rubber. The gauges are then to be removed and the process continued.

63 Before a fresh piece of asphalte is spread, the edge of the spread asphalte is to be melted by passing a red hot iron over it, to make the connection between the two pieces perfect. Should there be a defect in any joint, live charcoal should be placed on the part to soften the asphalte, and if necessary fresh asphalte added, and the part rubbed smooth with a hot trowel or hard wood rubber.

64 A ton of pure Val de Travers' asphalte with 30 per cent of fine grit will lay superficial yards as follows:—½" thick—40 yards; ¾" thick—30 yards; 1" thick—20 yards; 1¼" thick—17 yards; 1½" thick—15 yards. Work thicker than 1" must be laid in two coats, the first coat being allowed to set before the second is added.

65 **Earthern floors—Renewal of in stables.**—The old earth will be dug up from the whole stable and removed before any new earth is put down.

66 The new earth is to be a clay, and not a sand or mould It is to be laid in 6 inch layers No water is to be used if the earth is fresh and in consequence damp, and even if this is not the case only a little water is to be sprinkled on with the hand The less water used, the *better will the floor be*

67 After laying and spreading it is to be consolidated until very little mark can be made on it with the heel of a boot

68 The fresh earth is to be taken from the spot ordered by the A. C R E and from no other

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Woodwork.

1 **Framing.**—Woodwork will be of teak, sal, deodar, chir or other sound wood locally procurable as specified

2 All wood used must be thoroughly seasoned completely free from sapwood, large knots shakes and other defects

3 The framing or timbers will be dressed and planed to the full dimensions shown on the drawings, or as directed by the A C R E

4 **Joints, &c.**—Great care must be taken that all *mortise and tenon joints, scarfs, &c*, fit fully and truly In order to guard against careless workmanship or failures from decay joints are to be designed, as far as possible so that the bearing surfaces of working parts are thrown to the outside and exposed to view Simple joints, being much more likely to be truly and securely made are always to be used in preference to more elaborate ones Joints will always be coated with white lead before the frames are finally put together

5 In constructing trusses a drawing of the truss full size, is first to be made on a level platform, from which templates of all tenons, mortises and scarfs, &c, are to be made as a guide to ensure all the trusses being of the same size

6 Timber buried in the ground should be charred and tarred Woodwork exposed to the weather should be tarred, varnished, oiled, or painted, if the wood is seasoned, otherwise it should be allowed to remain until seasoned, as coating it will do more harm than good by confining the natural juices of the wood, and will only hasten the decay of unseasoned timber

60 To mix the asphalte, first lay in the bottom of the caldron about ¼ of the bitumen to be used, and heat over a wood fire. When this is dissolved, one third fill the caldron with pieces of mastic of not more than about 5 lbs each. As the mastic softens and melts it must be well stirred and more pieces added until the caldron is nearly full, adding ½ of the bitumen gradually. When the whole is well melted and thoroughly stirred the sand or grit will be added gradually and the whole stirred until the grit is well incorporated with the mastic; the rest of the bitumen (¼) will then be added. The mixture is ready for use when small jets of steam are being given off and when it will fall freely from the stirrer. None of the composition should adhere to a clean cold iron rod when dipped into it.

61 Strict supervision is required in mixing to prevent too large a proportion of the bitumen being added. Workmen are tempted to do this as the asphalte when so mixed is laid with greater ease than when the proper proportions are used. In hot climates the smallest possible quantity of bitumen which will enable the men to work the material will be added.

62 When the preparation is ready for use, the boiling mixture is to be taken from the caldron with an iron ladle and laid on in rectangles 3 × 2 between wooden gauges, and spread evenly with a hot trowel to the requisite thickness. After one piece is spread the surface is to be sprinkled with clean sand, and rubbed smooth with a hard wood rubber. The gauges are then to be removed and the process continued.

63 Before a fresh piece of asphalte is spread, the edge of the spread asphalte is to be melted by passing a red hot iron over it, to make the connection between the two pieces perfect. Should there be a defect in any joint, live charcoal should be placed on the part to soften the asphalte, and if necessary fresh asphalte added, and the part rubbed smooth with a hot trowel or hard wood rubber.

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65 **Earthern floors—Renewal of in stables.**—The old earth will be dug up from the whole stable and removed before any new earth is put down.

66 The new earth is to be a clay, and not a sand or mould It is to be laid in 6 inch layers No water is to be used if the earth is fresh and in consequence damp and even if this is not the case only a little water is to be sprinkled on with the hand The less water used, the better will the floor be

67 After laying and spreading it is to be consolidated until very little mark can be made on it with the heel of a boot

68 The fresh earth is to be taken from the spot ordered by the A. C. R. E and from no other

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Woodwork.

1 **Framing.**—Woodwork will be of teak, sal, deodar, chir or other sound wood locally procurable as specified

2 All wood used must be thoroughly seasoned, completely free from sapwood, large knots, shakes and other defects

3 The framing or timbers will be dressed and planed to the full dimensions shown on the drawings, or as directed by the A C R E

4 **Joints, &c.**—Great care must be taken that all *mortise and tenon joints, scarfs, &c*, fit fully and truly In order to guard against careless workmanship or failures from decay, joints are to be designed, as far as possible, so that the bearing surfaces or working parts are thrown to the outside and exposed to view Simple joints, being much more likely to be truly and securely made, are always to be used in preference to more elaborate ones Joints will always be coated with white lead before the frames are finally put together

5 In constructing trusses a drawing of the truss full size, is first to be made on a level platform, from which templates of all tenons, mortises and scarfs, &c, are to be made as a guide to ensure all the trusses being of the same size

6 Timber buried in the ground should be charred and tarred Wood work exposed to the weather should be tarred, varnished, oiled, or painted, if the wood is seasoned, otherwise it should be allowed to remain until seasoned, as coating it will do more harm than good by confining the natural juices of the wood, and will only hasten the decay of unseasoned timber

7 *No woodwork is to be placed in position in a building or painted* until approved and passed by the A C R E or the person whom he may depute to do this duty

8 The ends of all beams, &c, which are to be bedded in walls, and the sides of timbers which are to abut against walls, shall receive three coats of coal tar laid on hot The tarring will be prepared as on page 58

9 Where the end of a beam, or any woodwork, is buried in masonry or brickwork, an air space of ¾ inch should be left all round

10 No woodwork of any kind will be set within 2 feet of a fireplace or flue

11 **Floors** —The boards, after having been dressed and planed perfectly square, true, and smooth, with parallel sides and ends, will be placed side by side, and their edges jointed by one or other of the following joints, the one to be used being specified in each case—*viz*, *shot* (*a*), *rebated* (*b*), *grooved and tongued* (*c*), *grooved and filleted* (*d*), *rebated and filleted* (*e*)



12 Their ends will always rest on a joist and may be shot The ends of no two boards next each other are to come together

13 They will be cramped into position by means of a carpenter's cramp, which is always to be used The cramp will not be removed until the nails have been fixed

14 The length of each board is not usually to exceed 8 feet, or its breadth 9 inches, nor must its thickness be less than 1½ inches

15 All boards will be fastened to joists and beams with nails of a length 2½ times that of the thickness of the board The nails will intersperse one another, each being spaced at one foot intervals

16 **General to all floors** —After the floors have been laid, they must be carefully planed over, and made perfectly true, level, and smooth

17 All special floors, such as double boarded, or double boarded with felt between, &c, must be specially specified

18 **Ceilings** —Wooden ceilings will be constructed with boards half an inch thick, of teak, deal, deodar, or any other wood as specified, the ceiling being fixed as shown in the plans

19 The boards are to be of uniform width not exceeding 6 inches and will be *shot, rebated, or grooved and tongued*, as shown above, as may be specified. They will be planed and dressed quite smooth on the under side and free from all inequalities.

20 **Cloth ceilings** may be provided when considered desirable. They will consist of good strong double warp cloth, like that supplied by the Elgin Mills Company at Cawnpore, the breadths of which will be well and strongly sewn together.

21 The cloth will be tightly, firmly, and smoothly stretched, when damp, and nailed on the upper sides of frames of convenient size.

22 These frames will be prepared on the floor and placed in position after the whitening is dry.

23 When the cloth shall have been fixed as above specified, it shall receive three coats of whitewash prepared as on page 57; lime must not be used.

24 **General**.—The contract rate will include all lifting and fixing in position of timber, with the cost of all necessary scaffolding, ladders, tackle, nails, spikes, &c., that may be required for the proper execution of the work, also the cost of the fitting of all ironwork.

25 All carpenter's work in position will be paid for by net measurements, no allowance being made for wastage, nor for dimensions supplied beyond those ordered.

26 As seasoned timber is becoming scarce and expensive, its use can be reduced by substituting steel for wood in trusses, reinforced concrete for verandah posts, stone or reinforced concrete for the chowkuts of doors and windows, &c.

Doors and Windows.

1 **Doors.**—In *Plates* XLV, XLVI, and XLVII are given drawings of different kinds of doors, while holdfasts are shown on *Plate* XIV.

2 Before putting together, all joints should be given a priming coat.

3 **Windows.**—Swing windows should be pivotted, and if necessary weighted, so as to close themselves; only one rope is then required.

4 Doors and windows should generally be made with square tops for the sake of economy.

5 **Locks** —Iron rim locks will be used for all ordinary barrack purposes where locks are required, but in barrack rooms a hasp and staple carrying a padlock is generally sufficient For magazines, locks will be of copper Their length must be specified in inches, as also whether right or left hand locks be required

6 If for special purposes a better class of lock be required, it must be specially specified

7 In fortified posts, arsenals and Government factories, the locks should be in series on the master key principle, with duplicate keys and labels

8 **Furniture** —The furniture, such as handles, must be strong and well secured, stout ring handles are to be preferred to knob handles, which latter must be cast or filled in solid to prevent their being indented

9 The keys should have solid bows, or if they be ring keys with an open bow, it must be filled in with brass before issue The bow should be engraved or stamped with M W on one side and with the number of building or room on the other

10 Each door or window will be furnished with one or more best barrel bolts per flap as shown in *Plate* XLV Their length must be specified in inches, and the upper bolt must be of such a length as to be within easy reach of a man standing on the floor The staple must always be fixed with two screws on each side When a better class of bolt is required, it must be specially specified

11 For outbuildings, and where otherwise specified, the Norfolk thumb latch, large, middling, or small, will be used

12 In loose boxes of stables, horse infirmaries, and localities in which projections are inadmissible, flush latches will be used

13 **Glazing** —The rebate for glass on the outside of a sash bar shall never be less than ¼ inch in depth, and ⅜ inch in width, standard sizes of panes will be used, and the distance between the rebates must always be very slightly in excess of the glass, the latter is nowhere to touch the woodwork of the frame, otherwise any jar to the frame would be liable to crack it

14 The whole sash bar, but especially the rebate which has to receive the putty, will first be well primed, to prevent the wood drawing the oil out of the putty The glass will then be firmly bedded in putty

15 The glass will be secured in the rebates by 'back putty' sloping from the inner to outer edge of rebate The back putty must be kept a little within the inner edge of the rebate, so that none of it may show through the glass from the inside Both front and back putty is *at once* to be covered with a coat of paint, to prevent it shrinking as the oil dries out of it Each pane will be further secured in position by four or more iron brads These are always to be completely hidden by the back putty

16 The weight and quality of glass to be used depends on the class of building For officers' quarters 21 oz, seconds, sheet glass is suitable

17 In reputtying panes of glass all the old putty is to be carefully removed and replaced by new, sprigs being also put in if there are none The rebates to be thoroughly cleaned and moistened with raw linseed oil before being reputtied

18 The glass both in new work and in replacing broken panes is to be thoroughly cleaned before the work is accepted as finished

19 For recipe of putty see page 57

Ironwork.

1 All wrought iron articles are to be manufactured from iron equal in quality to best Staffordshire, or of mild steel and to be approved by the A C R L before being fixed They are to be forged clean from the anvil and neatly, soundly, and perfectly finished For any special work a special specification must always be given

2 All edges must be filed square when directed and all bolt and rivet holes may usually be punched, but they must be drilled out if required

3 All bolts and nuts must be to Whitworth standard, both as regards threads and sizes of heads and nuts The heads and nuts are to be hexagonal All bolts must be screwed for a length of three diameters The screws of all bolts should show a full thread above the nut when the latter has been screwed up tight, any length beyond this amount being cut off

4 For cutting and tapping bolts and nuts Whitworth's taps and dies will always be used, and the thread will be full, true, and deep, without taper, and accurately fitted

5 All rivets must fit fully and truly, the holes made for them must be of the sizes, and in the positions, shown on the drawings, and if the rivets shake at all from the blow of a hammer, they must be cut out and replaced

6 All castings must be clean and sound, and entirely free from air holes or defects of any kind

7 Straps, bolts and other ironwork will be thoroughly cleaned from rust and dipped in boiling linseed oil before being fixed in the work

8 All ironwork will be paid for, and agreed for, by the cwt, and not by the maund

See also under Painting

NOTE — A more detailed specification for steel and ironwork ordered from local firms will be found in Appendix 30, Schedule C, P W D Code, Vol II

Painting.

1. **Woodwork.**— All exposed woodwork should be painted, unless otherwise specially directed, and it may often be desirable to protect interior woodwork also by painting or oiling The preservative quality of paint depends on the toughness and impermeability of the skin formed by the boiled linseed oil in combination with pigments. Everything added to this, such as driers, turpentine, inferior pigments, &c, tend to weaken the paint and reduce its life It is therefore of importance that none but the best boiled linseed oil and the soundest pigments should be used, and that no more driers, turpentine, &c, be added than is found to be absolutely necessary

2 Painting is best done departmentally or by piece work, and in all cases it is essential that all materials should be supplied and mixed departmentally, and precautions must be taken to prevent the addition of cheap bazar oils to the paint

3 **Materials** —The best quality of boiled linseed oil, known as "pale boiled oil," should be used It can be obtained of local manufacture and good quality from Ghorepara and elsewhere The pigments should be of a non-oxidisable, and non-soluble character

Good paints can now be obtained of Indian manufacture from the Shalimar Paint and Varnish Company, Calcutta. The paint should be ordered ready "ground in oil

4 **Mixing.**—Except for white paint no raw linseed oil should be used in the thinnings, and as a general rule in dry parts of India no turpentine or driers should be added. For white paint a proportion of raw oil and turpentine is necessary as with boiled oil only the paint is discoloured. In finishing coats if a specially good surface is required ⅓rd to ¼th of the thinning required may be of copal varnish instead of oil.

In mixing the paint, oil thinnings should be added to the pigment and well mixed until the paint flows freely from the brush.

5 **Preparation of woodwork.**—Before applying the paint the woodwork must be thoroughly cleaned, all projections removed, knots or holes covered, or filled in, with a preparation of red lead and glue size, laid on hot, called knotting. The knots in resinous woods, such as deodar, should be painted over with hot lime. After 24 hours the lime is scraped off, and the knots painted with red and white lead and linseed oil. When dry they will be pumice stoned smooth.

6 **Priming coat.**—This will be of red lead, or of red and white lead mixed in boiled linseed oil only. When dry, all cracks or holes are to be filled up with putty and the whole surface rubbed down with pumice stone or sand paper and well dusted.

7 **Second coat.**—The second coat will be of the desired colour, mixed as directed, and will be laid on in exactly the same manner as the priming coat. When dry the surface will be rubbed down with pumice stone, or glass paper.

8 **Third coat.**—If required, a third coat will be applied in the same manner as the preceding ones, greater care being necessary to prevent brush marks being visible on its completion.

9 **General.**—All woodwork must be properly seasoned and free from moisture in its pores before the application of paint, or dry rot may be caused.

The paint will be applied with brushes, and spread as evenly and as smoothly as possible. To effect this, as soon as the whole or a convenient quantity is covered, the brush should be passed over it in a direction contrary to that in which it is finally to be laid off, this is called *crossing*. After crossing, it should be laid off softly and carefully in a direction contrary to the crossing, but with the grain of the wood, taking care that none of the crossed brush marks be left visible. The

criterion of good workmanship is that the paint be laid evenly, and the brush marks be not observed In *laying off*, the brush should be laid into that portion of the work already done, so that the joining may not be perceived Every coat should be perfectly dry and passed by the officer in charge of the work, and all dust carefully removed, before the succeeding one is laid over it

The paint must not be allowed to settle in the cans, to prevent this each painter will have in his tin can a small smooth stick, with which he must be made to stir up the paint occasionally If it has to be laid on one side for a time in an open vessel, it should be covered with water to prevent oxidisation and drying

In painting doors and windows, the putty round the glass must also be painted, and after the completion of the final coat, all the glass must be cleaned, stains from paint, &c, being removed by the application of a little turpentine

10 **Repainting old work.**—The old paint will be carefully examined If firm and sound, it will be well rubbed down with pumice stone, greasy places being rubbed with turpentine It will then be given one renewal coat

If decayed, unsightly from the accumulation of many old coats, or otherwise unsound, it will be entirely removed and two or more new coats, with or without a fresh priming coat, as examination indicates, will be given as for new work Necessary cleaning of the woodwork and stopping should be given as required

The best way of removing old paint is by burning off with air pressure flare lamps.

11 **Varnishing** —The surface of the wood having been thoroughly cleaned, stopped and sand papered over, a coat of glue size will be given This will be made of selected clear glue of consistency to run freely in a brush when hot When dry, which will be in a few hours, or the following day, a coat of copal, oak or wainscotting varnish will be given, followed by a second coat if necessary

The hard drying copal or oak varnishes are suitable for interiors and furniture, and the heavier oil varieties of copal varnish where protection from the weather is sought.

12 **Wood oiling** —Earth oiling consists in the application of crude earth oil or petroleum, warmed till it flows freely from a brush,

to the surface of woodwork In the case of shingle roofs, a proportion of oxide of iron should be added to the oil to colour the shingles red

Where employed as a preservative on teak houses as in Burma, an annual coat is required both on roofs and exposed walls In India a coat applied every third year or so on unpainted timber, as in verandah roofs, &c, preserves the work from insect attacks and weather and the woodwork assumes a neat varnished appearance in time

13 **Painting Plaster.**—The plaster must be carefully laid and its surface free from air bubbles or flaws caused by the blowing of the lime It is essential that both the plaster and the wall be perfectly dry before painting is commenced There are several methods of applying the paint, all of which are influenced by the very absorbent nature of the plaster

14 The plaster may be primed with glue size to prevent absorption and then four coats of ordinary lead paint applied, or it may be primed with two or three coats of boiled linseed oil which when dry is covered with a thin coat of weak size tinged with red lead to stop all absorption and give the work a uniform appearance it is then finished off with two coats of oil paint

15 **Ironwork**—All ironwork should have the surface protected from rust before the work leaves the A C R E's workshop for when once the metal begins to oxidise the process is most difficult to arrest Paint or other protective coat will peel off if applied to a surface containing any particles of rust Whenever possible the metal while still "black hot" will be immersed in a trough of the best boiled linseed oil

16 If the metal has been allowed to grow cold before coating it must be thoroughly cleaned from rust and dirt by scraping or by brushing with steel wire brushes and then coated with best boiled linseed oil

17 Ironwork such as door holdfasts, cramps straps &c, will be coal tarred, the tar being mixed in the proportion of 4 parts tar to 1 part kerosine oil heated together

18 If it is considered desirable to paint the ironwork red lead is recommended for important structural iron or steel work For unimportant ironwork or for roofs red oxide of iron may be used This is obtainable of local manufacture from Kutni In mixing it a small quantity of turpentine is necessary

Roofing.

1 **Terraced Roofs—Flagging.**—These should be laid at a slope of not less than 1 in 20. The concrete may be supported on jack arches, flags or tiles.

2 **Concrete.**—The concrete will be composed of broken stone or broken brick of good quality, the largest pieces of which will be capable of passing, whichever way they are turned, through a ring one inch in diameter. This ballast will be steeped in water for four hours before being mixed with the mortar; the mortar and ballast will be mixed in the proportions determined by experiment at each station to be most suitable, and approved by the C. R. E.

3 The mortar will be composed as specified under that head.

4 The mortar and ballast will be thoroughly incorporated on platforms specially made for the purpose, as specified under the head of "Concrete."

5 **Consolidation.**—When the concrete is thoroughly mixed, it will be laid on the roof in one thickness of 8 inches deep. Care should be taken that the concrete is not in too fluid a state. When laid, it will be beaten with small round rammers 6 inches in diameter, until it shall have been reduced to 5 inches in thickness, and until the mortar shall have partially set. While this operation is under progress, the surface should be frequently tested, and kept perfectly true and even in the line of the outward slope specified, *viz.*, 1 in 20.

6 Two rows of coolies will next be placed on the roof along its entire width as close as they can sit, and will traverse the length of the roof backwards and forwards, beating with what is called a *thapi* (a wooden knife of the shape shown in the margin). This beating will continue until the mortar shall have almost set and until the *thapis* rebound from the surface readily when struck on it. This will usually be attained after three days.



7 While the beating is going on, the surface of the concrete will be liberally sprinkled with water, in which *gur* (coarse sugar) and *bael fruit* (wood apple) are dissolved in the following proportions, *viz.*, three and a half seers of *gur* and two seers of bael fruit to 20 to 30 gallons of water.

8 **Rendering surface.**—As soon as the beating shall have been completed as described, the surface will be softened by being sprinkled with pure water, and the mortar which has been brought to the surface by the beating will then be smoothed, and rendered with the face of a trowel

9 The surface should be worked to a very fine polish, and to assist this, fine lime putty may be used *sparingly* (the less the better), and as the process advances, the surface should be liberally sprinkled with water in which bael fruit and *gur* are dissolved in the proportions mentioned in para 7

10 **Surface**—No plaster is to be laid over the concrete on any account, as this, though a common practice, is often the source of great evil afterwards The fine polished surface, which it is advisable to give to the concrete, in order to allow water to run off speedily, will be *given, as already described, by rendering* the mortar brought to the surface perfectly smooth with the face of a trowel, and by means of lime putty sparingly used

11 **Watering**—As soon as the upper surface of the roof shall have been rendered thoroughly smooth, and a fine polish given to it, by the free use of the smooth surface of a trowel, it will be covered with 2 inches of fine sand or earth, and over this again will be placed a layer of grass mats, which should be kept thoroughly saturated with water until the rains shall have commenced

12 Junctions of terraced roofs with main clerestory walls will be secured by a drip course of the standard pattern, or when the wall has already been built, by laying a floor of roofing bricks 2 feet wide on the terrace, and let 3 inches into the main wall

13 The eaves, except otherwise ordered, will be finished off with a *plain cornice, formed of projecting bricks,* and plastered, or with a dwarf parapet wall and plaster reveals, or cast iron down pipes down the walls

14 **Mud roofing over bricks**—Terraced roofs are not suitable for dry climates like the Punjab, they invariably crack in the dry weather and leak badly when rain comes on Hence it is better to use mud over bricks laid as follows —

15 Mud roofing over bricks will consist of 6 inches of well tempered clay consolidated over roofing bricks 12 × 6 × 2 which will be laid dry over sawn rafters spaced at one foot central intervals, or will be jointed with mortar as may be ordered

16 The clay must be stiff white or red clay according to locality, and after being excavated is to be spread out to be scorched by the sun. It is then to be reduced to powder, and stacked in heaps of 100 cubic feet.

17 Water is then added and the clay is well mixed by treading with the feet and with phowrahs, until the whole assumes the consistency of stiff mortar.

18 It is then laid on the roof and well beaten until quite hard. It is then finished off with a coat of mud plaster, and leeped with cowdung as described in the specification for mud plaster.

19 **Allahabad Tiling.**—A full description of the manufacture of Allahabad Tiles will be found in the "Roorkee Professional Papers," Vol III, 2nd Series, page 146, by Major G. P. de P. Falconnet, R. E. The tiles should, however, always be burnt in Bull's Trench Kilns, the latest patterns of which are described in his pamphlets printed at Lahore.

20 Single or double Allahabad tiling will be used as specified or as directed by the A. C. R. E. In districts where high winds prevail this kind of roofing is unsuitable without a ceiling cloth, as it lets in hot air too freely in summer and cold air in winter with intolerable quantities of dust at both seasons. This can be remedied to a great extent by using the pattern of flat tile shown in *Plate* LVIII in the lower layer set in clay and lime pointed below.

21 **Double Allahabad Tiling.**—Double tiling will be laid as shown in *Plate* LVII, and will consist of layers of flat tiles laid on battens, the latter being secured to the common rafters. The side edges of every two adjacent flat tiles will be covered by a semi-hexagonal tile; over these semi-hexagons will be laid another layer of flat tiles, the adjacent edges of every two of the latter being again covered by a semi-cylindrical tile.

22 **Single Allahabad Tiling.**—Single tiling will consist of a layer of flat tiles laid as described for the lower layer of double tiling, but having the adjacent two edges of each row covered with a row of semi-cylindrical tiles.

23 **General.**—All tiles used must be thoroughly burnt, of uniform colour, and free from twisting and other imperfections. They must be of a dark red colour, and must ring clearly when struck. The three lowest tiles in each layer, over the walls and next the eaves, will be set in fine mortar.

24 All tiles must fit closely and well, in the position shown in *Plate* LVII, the moulded niche at the lower end of each flat tile fitting completely in the bead of the tile next below it and the buttons at the upper end must have a firm hold on the wooden battens, placed at one foot intervals, to receive them

25 Each semi hexagon must fit exactly in its position, both on the flat tiles under it and also into the bed specially formed, in the upper part of the next semi hexagon to receive it

26 The upper layer of flat tiles must be exactly the thickness of the semi hexagon They will then exactly overlap each other by 3 inches, and yet fit in the position made for them on the semi hexagonal tiles, the lower buttons taking the lugs moulded on the sides of the semi hexagons to receive them

27 Over this upper layer of flat tiles, and covering the two adjacent edges of every row, will be laid a row of semi cylindrical tiles, which must again fit exactly on to the flat tiles, the shoulder of the niche cut out of each coming in close contact with the lower edge of the flat tile under it, and the buttons towards the lower end will lie exactly on the upper edge of the semi-cylindrical tile next beneath it

28 The ridges, and hips when existing, will be covered by the tiles specially manufactured for these positions, and as shown in the drawings in Major Falconnet's article

29 The three lowest tiles in each course, also all ridge and hip tiles, will be soaked in water for four hours, set in fine sound mortar, and will be well watered for five days after laying, but no mortar is on any account to be used in any other part of a tiled roof

30 A wood rasp may be used in making the tiles fit completely and closely, but any tile which cannot be made to fit with its neighbour closely, without injury from rasping must at once be rejected

31 When the roof covering is completed, all the lines of the tiling must be perfectly even and straight This will best be observed by noticing the diagonal lines made on the roof by the ends of the semi cylindrical tiles

32 For specification and instruction as regards the manufacture of bricks* and tiles, Major Falconnet's article above referred to should be consulted

48 The bolt holes must be slightly larger than the diameter of the bolt, so as to allow of contraction and expansion of the mass of the roof covering. These holes must be covered by a leaden washer fitting tight to the shank of the bolt, and extending ½ an inch all round beyond the hole.

49 All rivets, bolts, &c., will be set in white lead.

50 The ridge and hips (where such exist) will be covered by a substantial galvanised iron or zinc capping, which will be rivetted, according to the method described above, to the corrugated iron. This capping will be laid in lengths, with an overlap of at least 9 inches at each joint between two lengths, the joint being set in white lead.

51 The sheeting should not be built into the gable end parapet walls, the long edge should be well bent up, and a drip course built into the parapet should cover the end by at least 3 inches.

52 A water tight joint can be made between the fastening and sheeting by the use of Price's Limpet Washers, in place of rivets. These washers when screwed down adapt themselves exactly to the curve of the corrugation and need not be set in white lead. Patent bolts to suit the peculiar shape of the washers are made and should be used with them. Even where skilled labour is not obtainable a good and impervious roof can be made with the Limpet Washer and bolts.

53 When galvanised iron is laid on framing of deodar, steps must be taken to prevent the deodar touching the galvanised iron, otherwise the galvanising will be destroyed by chemical action.

54 Sheet iron roofing can also be laid without making any holes in the sheets for bolts or rivets by either of the two following methods :—

55 **I.—McKenzie's Naini Tal pattern.**—The roof covering will consist of 24 B. W. G. plain or corrugated iron, galvanised or ungalvanised, as may be specified. When ungalvanised iron is used, the lower surface of each sheet will receive a coating of coal tar laid on hot, before being placed in the roof.

56 The sheeting will be laid on planking of chir, deodar, or other wood of the thickness specified. The planks in barrack roofs will touch each other laterally, and in subsidiary buildings be spaced at intervals equal to their breadth. The planking will be secured to the rafters by 3 inch screws, spaced as may be directed by the A. C. R. E. If

24 All tiles must fit closely and well, in the position shown in *Plate* LVII, the moulded niche at the lower end of each flat tile fitting completely in the head of the tile next below it and the buttons at the upper end must have a firm hold on the wooden battens, placed at one foot intervals, to receive them

25 Each semi hexagon must fit exactly in its position, both on the flat tiles under it and also into the bed specially formed, in the upper part of the next semi hexagon, to receive it

26 The upper layer of flat tiles must be exactly the thickness of the semi hexagon They will then exactly overlap each other by 3 inches, and yet fit in the position made for them on the semi hexagonal tiles, the lower buttons taking the lugs moulded on the sides of the semi hexagons to receive them

27 Over this upper layer of flat tiles, and covering the two adjacent edges of every row, will be laid a row of semi cylindrical tiles, which must again fit exactly on to the flat tiles, the shoulder of the niche cut out of each coming in close contact with the lower edge of the flat tile under it, and the buttons towards the lower end will lie exactly on the upper edge of the semi-cylindrical tile next beneath it

28 The ridges, and hips when existing, will be covered by the tiles specially manufactured for these positions, and as shown in the drawings in Major Falconnet's article

29 The three lowest tiles in each course, also all ridge and hip tiles, will be soaked in water for four hours, set in fine sound mortar, and will be well watered for five days after laying, but no mortar is on any account to be used in any other part of a tiled roof

30 A wood rasp may be used in making the tiles fit completely and closely, but any tile which cannot be made to fit with its neighbour closely, without injury from rasping, must at once be rejected

31 When the roof covering is completed, all the lines of the tiling *must be perfectly even and straight* This will best be observed by noticing the diagonal lines made on the roof by the ends of the semi-cylindrical tiles

32 For specification and instruction as regards the manufacture of bricks* and tiles, Major Falconnet's article above referred to should be consulted

33 **Mangalore Tiling.**—This tiling will be of thoroughly burnt Mangalore tiles laid fair and square and properly fitting, with the catches resting fully against battens nailed 12½ inches from centre to centre to the upper surface of the rafters, and exactly at right angles to their direction. Care must be taken that each course is laid perfectly parallel to the rafters.

34 Below the channel or edge of the lowest or eaves row of tiles a batten of extra thickness is to be used to make the slope even and continuous from ridge to eaves.

35 The ridge and hip tiles will be set in the best lime mortar, and where high winds prevail, the ends of the eaves tiles will be nailed with iron nails or secured by wire to the eaves batten, unless the eaves are bedded on to a masonry cornice, or a planked ceiling is given below them.

36 In excessively wet places it is advantageous to coat the beds or channels of the tiles well with tar.

37 To make a Mangalore tiled roof absolutely water tight, a planked ceiling should be given below the tiles to be covered with strong dungry cloth laid in lengths parallel to the boards, and each width overlapping that below it at least 3 inches. The whole to be well tarred. (*See Plates* LIX and LX.) Ceiling tiles for use with Mangalore tiles are also obtainable.

38 **Corrugated Galvanised Iron Roof Covering.**—The corrugated iron will be of the gauge specified by the A. C. R. E. The surface of the sheets must be clean and bright and free from rust. Any sheets showing a white powdery deposit should be rejected.

39 The purlins to which the sheets will be fastened will run in horizontal lines along the length of the roof. There should be one at each end, and one in the middle of each sheet.

40 Each sheet will be laid on the roof with a lap of 6 inches in its length, the side laps will extend over two corrugations, when the latter are small, and over one when they measure about 5 inches or more. The use of sheets having large corrugations is, however, to be avoided. Vertical laps should be turned away from the rainy quarter.

41 The sheets should be rivetted together in sets on the ground. Generally three sheets in length, and three or four in breadth, can be completed on the ground, before they are hoisted on to the roof.

42 In rivetting up the sets, the sheets should be placed on trestles about 2 feet high, so that men may be able to work comfortably underneath. *The rivet holes must be punched from below, upwards, so that the arris may be at the top.* The tools must be very sharp, so that there may be no tearing of the sheet, and the hole must be clean punched out.

43 These rivet holes will be placed at from 1 to 2 feet intervals along the edge of the lengths of the sheet, or at such distance approximating to above, as will equally divide the sheet along its length. At the tops and bottoms, each sheet will be rivetted at the corners, and at least once in its breadth.

44 At the corners, where the rivets have to go through four sheets, it is better to drill the holes from below. All holes will be in the ridges, and never in the gutters of the corrugations.

45 In fixing the rivets, which will always be of galvanised iron, they will be passed through from below, and held up firmly by a bolster resting on a block of wood placed on the ground. A leaden washer fitting tight to the shank of the rivet, and extending ½ inch all round beyond the edge of the hole, will be put on, and the rivet head will be made over it with a light hammer, and finished off with a cupping tool. Great care must be taken that the sheet be well supported underneath, and that no indentation be made on the upper surface of the corrugation.

46 The different sets will then be hoisted on to the roof, and will there be rivetted together in the same manner as the separate sheets were joined below. As in this case the holes through two sheets must be made simultaneously, and as there is more difficulty in blocking the sheets than on the ground, it is generally preferable to drill the rivet holes, but still from below.

47 When the sheets have been connected in this way on the roof, they have to be secured to the timbering. This is always to be done by means of clips or hooked bolts, passing through the sheets, and round the timber. The sheets are not to be screwed to the timbers. The bolts will be placed at some of the corners where four sheets overlap each other (*see Plate* LXXI). Excellent rounded iron clips with little bolts and washers are now provided by all makers for fixing the sheeting to steel purlins, and their use is recommended. All clips, bolts or hooks must be galvanised.

48 The bolt holes must be slightly larger than the diameter of the bolt, so as to allow of contraction and expansion of the mass of the roof covering. These holes must be covered by a leaden washer fitting tight to the shank of the bolt, and extending ½ an inch all round beyond the hole

49 All rivets, bolts, &c, will be set in white lead

50 The ridge and hips (where such exist) will be covered by a substantial galvanised iron or zinc capping, which will be rivetted, according to the method described above, to the corrugated iron. This capping will be laid in lengths, *with an overlap of at least 9 inches* at each joint between two lengths, the joint being set in white lead

51 The sheeting should not be built into the gable end parapet walls, the long edge should be well bent up, *and a drip course built into the* parapet should cover the end by at least 3 inches

52 A water tight joint can be made between the *fastening* and sheeting by the use of Price's Limpet Washers, in place of rivets. These washers when screwed down adapt themselves exactly to the curve of the corrugation and need not be set in white lead. Patent bolts to suit the peculiar shape of the washers are made and should be used with them. Even where skilled labour is not obtainable a good and impervious roof can be made with the Limpet Washer and bolts

53 When galvanised iron is laid on *framing* of deodar, steps must be taken to prevent the deodar touching the galvanised iron, otherwise the galvanising will be destroyed by chemical action

54 Sheet iron roofing can also be laid without making any holes *in the sheets for bolts or rivets by either of the two following* methods —

55 **I —McKenzie's Naini Tal pattern.**—The roof covering will consist of 24 B. W. G. plain or corrugated iron, galvanised or ungalvanised, as may be specified. When ungalvanised iron is used, the lower surface of each sheet will receive a coating of coal tar laid on hot, before being placed in the roof

56 The sheeting will be laid on planking of chir, deodar, or other wood of the thickness specified. The planks in barrack roofs will touch each other laterally, and in subsidiary buildings be spaced at intervals equal to their breadth. The planking will be secured to the rafters by 1¼ inch screws, spaced as may be directed by the A. C. R. E. If

corrugated iron sheeting be used it may be laid on purlins spaced as directed in para 39 of the foregoing specification

57 The battens B (*see Plates* LXIII, *Figs* 2 and 5, and LXIV) 2" × 1½ will be secured to the planks by screws 3 inches long, and 3 feet apart driven from below The ends of the battens at the eaves will be rivetted through to the planking, with an iron rivet ⅜ inch diameter, with washers 1½" × 1½" × ⅛" at each end of the rivet (*see* C, *Plate* LXIV)

58 The sheets will have their longitudinal edges curved, by first hammering them with a wooden mallet, with a curved head, on a wooden platform the other side of the sheet being gradually elevated, until the edge under treatment has assumed the form required approximately The edge is then finished off, by being hammered with the same mallet round a wooden bar of the required shape The sheet thus prepared will be placed on the roof, and will be secured to the planking at its upper edge by one 1¼ inch screw (*see* F, *Plate* LXIV) placed 1½ inches from the upper edge of the sheet, and half way between the battens The sheets are held down at their edges by three iron clips 3⅞" × ¾ × ⅛" (*see* E, *Plates* LXIII, *Fig* 2 and LXIV) countersunk into the battens The clips are made from the iron bands, which are used to bind the bundles of iron for transport, and will be screwed down to the battens with 1¼ inch screws, ½ an inch apart in the clear

59 The rolls or covering strips (*see* A, *Plate* LXIV) will be of plain sheet iron galvanised or not to accord with rest of roof, of 22 B W G The strips will be hammered round a wooden bar of proper shape with the wooden mallet mentioned in para 58, and when nearly of the shape required, an iron ring of proper shape will be placed over the roll and wooden bar at one end, and hammered down the bar to the other end, thus forcing the roll to assume the exact shape of the wooden bar The rolls will then be slipped on to the battens and each secured by one 1¼ inch screw (*see* H, *Plate* LXIV) placed 1½ inches from the upper edge of the roll

60 The ridge will then be covered in with specially shaped ridging or plain iron sheeting, galvanised or not to accord with rest of roof, of 18 B W G These sheets will be 2 feet wide, and will be curved along their upper edges in the manner described in para 58 They will be laid on the battens supporting the rolls, or on planking screwed to the

battens, overlapping each other longitudinally by 9 inches (*see* G, *Plate* LXIV), the joint or overlap being set in white lead To secure these sheets, clips KK, 13" × 1" × $\frac{3}{16}$" will first be screwed down to the battens (through the planking) with two 2 inch screws (*Plates* LXIII, *Figs* 1, 2, and LXIV) The lower edge of each sheet will then be inserted in the clips, and the upper curved edge of the sheet brought against the ridge pole, where it will be secured in the manner described in para 58 (*Plate* LXIII, *Fig* 2), thus leaving neither screws nor rivets exposed A wooden fillet 1 9" × 1½" × ¾" should be inserted under the end of the rolls A to prevent the screws holding down the clips K flattening them out (*Plate* LXIII, *Fig* 1) The special shaped ridging if used will be fixed at its edges by similar clips as described above, and if considered necessary will be further secured by galvanised iron screws to the ridge plate

61 The ridge sheets being fixed will be covered by a roll similar to those specified in para 59 running along the whole length of the ridge (*Plate* LXIII, *Fig* 2)

62 Each sheet and roll at the eaves must be held down by an iron clip (*see* L and M, *Plates* LXIII, *Figs* 5, 6, and LXIV,) screwed to the planking, and passing over the end of the sheet or roll (two clips L should be given to sheets more than 2 feet wide) This is to prevent the wind getting between the sheet and the planking, and raising the former up at its lower extremity

63 When ungalvanised iron is used, on the completion of the work the roof covering will receive two coats of Olphert's paint, laid on as specified under "Painting," after the surface has been thoroughly cleaned and all signs of rust removed by scraping and brushing This must be done in fine dry weather

64 The drawing given in this Handbook (*Plates* LXIII and LXIV) are for plain sheets 6 × 2

65 **II —LeMesurier system** —The roof covering will consist of plain sheet iron, galvanised or ungalvanised as may be separately specified, and of the gauge decided on Ungalvanised iron will be given a coat of tar laid on hot on the underside before being placed in position, and will receive two coats of Olphert's paint after laying is completed

When no ridge planking is laid and sheets 3 feet broad are used for the roof the ridging should be of 20 B W G sheet iron except in

unexposed situations, in other cases 22 B W G sheets may be used for the ridging

Before laying, the sheets (when not imported in a finished condition) will be bent in a press, after pressing, the two long sides of the sheet will be as in *Fig* 4, *Plate* LXI

66 The sheeting will be laid on planking of the timber separately specified. The planks will be 6 or 7 inches broad and 1 inch thick laid horizontally. In the majority of stations when the span does not exceed 25 feet, it will be found most economical to lay this boarding direct on the wooden principal rafters of trusses. The distance apart of these trusses, or of the common rafters where purlins are used, should not exceed 6 feet with local planking of average quality. Before the sheets are laid the planking and battens will be given one coat of tar laid on hot. In subsidiary buildings the sheeting may be laid either on "open boarding" or on purlins as with corrugated iron

67 The battens will be 6 inches long by 1½ inches broad rounded on the top to a semicircle of ¾-inch radius—they should be roughly cut from any scraps of wood which may be available. They will be fastened to the planking by one 1¾ inch screw driven from above and by one 2 inch screw driven diagonally through the clip as shown in *Fig* 4, *Plate* LXI. One batten is required for each clip

The battens will be tarred on the underside before laying

68 The clips for joining the sheets laterally will be made of 1½ × 14 B W G mild steel hoop and will be of the form shown in *Fig* 6 *Plate* LXI. When the sheets are galvanised, they should be galvanised also, otherwise they should be tarred hot. They should be fixed to the roof planking and battens by two 1 inch screws and one 2 inch screw as shown in *Fig* 4

The ridge clips will be of the form shown in *Fig* 2, the short end before fixing being as in *Fig* 6. The gauge and number of screws will be as for the roofing clips described above

When [illegible] × 2 sheets are used for the roof covering, one clip is required at the centre and at each end of the long sides of each sheet, with [illegible] × 3 (except in unexposed situations) and 8 × 3 sheets four clips should be given on each side, one being placed distant a third of the length of the sheet from each end. The clips at the top and bottom

battens, overlapping each other longitudinally by 9 inches (*see* G, *Plate* LXIV), the joint or overlap being set in white lead. To secure these sheets, clips KK, 13" × 1" × $\frac{3}{16}$" will first be screwed down to the battens (through the planking) with two 2 inch screws (*Plates* LXIII, *Figs* 1, 2, and LXIV) The lower edge of each sheet will then be inserted in the clips, and *the upper curved edge of the sheet brought against the* ridge pole, where it will be secured in the manner described in para 58 (*Plate* LXIII, *Fig* 2), thus leaving neither screws nor rivets exposed A wooden fillet 1 9" × 1½" × ¾" should be inserted under the end of the rolls A to prevent the screws holding down the clips K flattening them out (*Plate* LXIII, *Fig* 1) The special shaped ridging if used will be fixed at its edges by similar clips as described above, and if considered necessary will be further secured by galvanised iron screws to the ridge plate

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63 When ungalvanised iron is used, on the completion of the work the roof covering will receive two coats of Olphert's paint, laid on as specified under "Painting," after the surface has been thoroughly cleaned and all signs of rust removed by scraping and brushing This must be done in fine dry weather

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When no ridge planking is laid and sheets 3 feet broad are used for the roof the ridging should be of 20 B W G sheet iron except in

The sheets in the last line (on the windward side) have in all cases to be specially bent, as the two long sides must be similar, and usually require to be cut to a special breadth. The sheets should be laid from the eaves upwards, the uppermost sheet being cut to such a length as will ensure the ridging sheet overlapping it by at least 10 inches and its upper edge should be turned up approximately in the form of a semi circle of $\frac{1}{2}$ inch diameter, the long edges being cut to enable this to be done.

Note.—With inexperienced work people it is advisable to lay the battens and sheeting simultaneously as the work proceeds, the work on the battens being kept slightly ahead of the laying of the sheets. When the carpenters in charge fully understand the work it will be found best to lay all the battens first. When it is necessary to lay a large roof as quickly as possible two parties should be employed, one fixing the sheets and clips, the other the battens.

71. The ridging will be laid on the same principle with a special clip as in *Fig. 2, Plate* LXI.

The breadth of the ridge sheets will be separately specified, but should usually be 2 feet before pressing.

The ridge sheets may be bent in the same press as the roof sheets, the necessary splay on either side being given by driving hard wood wedges of the proper shape under the sheets while still in the press.

The ridge sheets should overlap at least 6 inches longitudinally, and should as a rule be laid on planking as shown in *Fig. 2*. In subsidiary buildings it may be laid direct on the uppermost battens.

For an elevation of the roofing *see Plate* LXII.

Flashings.

1. Gutters or flashing will be of milled lead weighing 6 lbs. per superficial foot, or, where cheapness is of importance, of zinc sheeting as may be specified. They must be so arranged as to give free play for expansion and contraction in any direction.

2. When the edges of sheeting are turned up, as in gutters, against the side of a chimney shaft, or against a wall, the edge should be left free instead of being fixed by being turned into the joints of the brick work or masonry, and a flashing, secured along the joints of the masonry, be bent over the up-turned edge of the gutter sheeting, which it should overlap about 4 inches; thus one edge of each piece of sheeting is left free to expand and contract.

3 The upper edge of the flashing may be fixed by being tucked into the joint, which will be raked out for a depth of about 2 inches, and wedged in with small plugs of wood The joints will be finally filled in with mortar

4 The flashing should be stepped, each step being cut back so as to keep out the weather better

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Lightning Conductors.

1 A complete arrangement of lightning conductors should be provided for all important magazines Smaller and less important magazines, important buildings, such as churches, &c, should also be provided with lightning conductors on a less elaborate system, but with good joints and earth connections

2 Barrack buildings should be provided with conductors when experience has shown that the locality is attractive to lightning discharge

3 The conductors may be of iron or copper, whichever is most convenient in each case, but they should be of the same material throughout The conductivity of the copper used is absolutely unimportant, except that high conductivity increases the surges and side flashes, and therefore is positively objectionable It is for this reason that iron is so much better

4 Solid rods, tubes, strips, and wire ropes of the same material and of the same superficial area or weight per foot run are considered to possess practically the same conducting power to lightning, which is electricity of high potential

5 A number of small conductors well connected at top and bottom provide a better protection to a building than an equal amount of metal, in large conductors, disposed at greater intervals

6 For main conductors, copper weighing not less than 6 oz per foot run, either in the form of tape or rope of stout wires—no individual wire being less than No 12 S W G —may be used Iron conductors possess advantages over copper conductors A suitable size of stranded iron conductor for ordinary buildings is $\frac{3}{8}$" soft galvanised iron rope, but for church towers and other inaccessible places a much larger diameter is preferable on account of the difficulty and expense of replacing it when rusted Iron conductors, whether galvanised or not, should be

painted Subsidiary conductors for connecting metal ridging, &c, to earth may with advantage be of iron and of a smaller gauge, such as No 4 S W G galvanised iron wire

7 There is no reliable rule concerning the area of protection given by a conductor of given height Any object to be thoroughly protected from lightning must be furnished as described with proper conductors

8 Conductors even on the most important magazines can be spaced at intervals of 50 feet, but no point on the building should be more than 25 feet horizontally distant from a lightning rod

9 When a tall chimney or other inaccessible erection has to be protected from lightning, the best plan is to carry a continuous conductor up one side and down the other, to use two earth connections, and to employ a connecting conductor just above the ground line, as shown on *Fig* 4, *Plate* LXX, and also one round the outside of the top of the cap and a few inches below it with terminals projecting 1 foot above the top of the shaft at intervals of 3 or 4 feet all round The most suitable conductor for this purpose is iron rod but special care must be taken with the joints A similar arrangement is suitable for church spires

10 The angles and prominent portions of a building being most liable to be struck, the lightning rods should be fixed on gable ends, chimney turrets, &c, and they should be connected together by continuous conductors along ridges

11 In all situations where several conductors are joined in one system, the vertical conductors should be connected both at the top and near the ground line The horizontal conductor used for the latter operation should be carefully connected to the earths, and all the joints to it should be above ground both for inspectional purposes and to prevent local galvanic action The connections between the lower horizontal conductor and the earths should be arranged as vertical continuations of the main rods

12 As far as practicable it is desirable that the conductors be connected to extensive masses of metal in close proximity to them, such as hot water pipes, &c, both internal and external but they should be kept away from all soft metal pipes and from internal gas pipes of every kind It is advisable to connect church bells and turret clocks with the conductors

3 The upper edge of the flashing may be fixed by being tucked into the joint, which will be raked out for a depth of about 2 inches, and wedged in with small plugs of wood The joints will be finally filled in with mortar

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painted. Subsidiary conductors for connecting metal ridging, &c., to earth may with advantage be of iron and of a smaller gauge, such as No. 4 S. W. G. galvanised iron wire.

7. There is no reliable rule concerning the area of protection given by a conductor of given height. Any object to be thoroughly protected from lightning must be furnished as described with proper conductors.

8. Conductors even on the most important magazines can be spaced at intervals of 50 feet, but no point on the building should be more than 25 feet horizontally distant from a lightning rod.

9. When a tall chimney or other inaccessible erection has to be protected from lightning, the best plan is to carry a continuous conductor up one side and down the other, to use two earth connections, and to employ a connecting conductor just above the ground line, as shown on *Fig. 4, Plate LXV*, and also one round the outside of the top of the cap and a few inches below it with terminals projecting 1 foot above the top of the shaft at intervals of 3 or 4 feet all round. The most suitable conductor for this purpose is iron rod, but special care must be taken with the joints. A similar arrangement is suitable for church spires.

10. The angles and prominent portions of a building being most liable to be struck, the lightning rods should be fixed on gable ends, chimneys, turrets, &c., and they should be connected together by continuous conductors along ridges.

11. In all situations where several conductors are joined in one system, the vertical conductors should be connected both at the top and near the ground line. The horizontal conductor used for the latter operation should be carefully connected to the earths, and all the joints to it should be above ground, both for inspectional purposes and to prevent local galvanic action. The connections between the lower horizontal conductor and the earths should be arranged as vertical continuations of the main rods.

12. As far as practicable it is desirable that the conductors be connected to extensive masses of metal in close proximity to them, such as hot water pipes, &c., both internal and external, but they should be kept away from all soft metal pipes, and from internal gas pipes of every kind. It is advisable to connect church bells and turret clocks with the conductors.

13 Metallic continuity should be ensured at the joints of all conductors. The joints of conductors should be rivetted, screwed, spliced or otherwise mechanically joined. They may also be soldered, but no reliance should be placed on a soldered joint without mechanical connection in addition, as the solder is seldom sweated through the joint and often consists of an imperfectly adhering mass of metal hiding badly fitting and dirty surfaces. For these reasons it is considered preferable to ensure good metallic contact by mechanical means, and to exclude damp from the joint by paint or other means. In rivetting tapes, five rivets should be used and the holes should be bored not punched. The sharp edges being removed, and the surfaces brightened with emery, the joint should be brought together with a hollow punch before rivetting. When solder has to be used it should consist of equal parts of tin and lead for copper conductors, and for iron conductors molten zinc should be used. There should be no joints under ground, but, if unavoidable, such joints should be covered with tarred tape. The joints should each possess a surface area equal to at least six times the sectional area of the conductor.

14 The "lightning rods" or terminals should project 3 feet in the air above that portion of the building (gable, pinnacle, &c.,) to which it is attached, and should preferably be of the same metal as the conductors. At the main features a four point rod should be provided, single point rods being used for subsidiary features. Where appearance is not of great moment a very good plan is to form the points by opening out the strands of the copper or iron rope conductors itself. The oxidation of the points does not impair the value of the rod.

15 Where tape is used the connection between the lightning rod and the conductor is made by means of a slotted clamp similar in design to those employed for test or other joints. The lightning rod terminates at its lower extremity in a ¾ inch bolt, which is screwed into the clamp thereby making firm contact with one or more tapes inside it. This joint admits of visual inspection—(*see Plate LXVI*)

16 Earth connections are of two kinds—deep and surface. In important cases both kinds should be provided, unless the permanent water level is very near the surface. The reason for this being that sometimes (after drought) the induced earth charge is collected on a damp substratum, when a deep earth is necessary, and sometimes (after rain) it is collected on the surface, when a surface earth is necessary. A deep earth

will generally be a well or at least permanently damp soil If a well it should not be less than 3 feet in diameter, and be carried down 10 feet below water level in the driest seasons The bottom 10 feet should have no mortar or cement in the walls The conductors will be led into the well, and rivetted and soldered to a plate resting at the bottom of the well of at least 24 square feet of outside surface If the conductors are of copper, the earth plate may be of copper 2 × 6 × ⅛, if they are of iron, the earth plate may be of galvanised sheet iron 2 × 6 × ¼" Or the end of the conductor may be coiled spirally on a wooden frame, the external diameter of the coil being 4 feet with 6 inch intervals between the turns. About 100 feet of tape is required for this connection which obviates the necessity of any underground joint Iron water pipes answer admirably as deep earths, but gas pipes must not be used as such, as accidents have been occasioned by a lightning discharge along a gas main breaking the pipe at the joints, and igniting the gas Wells supplying drinking water should not be used for copper earths

17 When neither a well nor iron water pipes are available for a deep earth, the conductor must be carried down to the dampest soil available in the manner described below The conductor must be bent and carried away from the building along the bottom of a trench 4 feet deep for a distance of not less than 30 feet at this point a circular pit 4 feet in diameter is to be dug across the middle of the bottom of which an earth plate is to be set up vertically, and connected in the usual way with the conductor The pit on both sides of the plate is to be filled up with charcoal or coke to the level of the upper edge of the plate In cases where permanently damp soil is not to be obtained a pipe may be carried up from the centre of this mass to the surface of the ground, and earth filled in all round it Whenever practicable surface drainage and roof down pipes should be arranged to discharge into the pit's mouth, and during the dry season water should be poured down the pipe

18 Surface earths, which are to be given in addition to deep earths in important cases, may consist of trenches 25 to 50 feet long according to the dampness of the soil 1 or 2 feet deep, filled with coke and ashes and carried away from the building The end of the metal conductor should be carried along the bottom and through the whole length of each trench

19 The portion of the conductor between the building and earth connection may be in shallow horizontal trenches, surrounded on all sides by [illegible] inches of coke or charcoal

20 Conductors should be fixed to the walls of buildings with small staples of the same metal as the conductors themselves

21 In erecting conductors unnecessary bends are to be avoided All bends should be gradual, sharp re-entering angles are not admissible In order to ensure this, the conductors may be led with an easy curve round large projections by means of holdfasts supporting the conductor a few inches away from the wall When this is impracticable conductors should be taken through the projections

22 Conductors should be tested immediately after erection and once a year at the end of the dry hot weather This will be carried out by the Garrison Engineer, or competent Subordinate, in the manner described in the "Code of Instructions for the Guidance of Public Works Officers in the Erection and Testing of Lightning Conductors," 1904, published by the Government of India, but visual inspection as to the mechanical and electrical conditions of the conductors above ground is to be chiefly relied upon, and electrical tests for the condition of the earths

23 A record of such tests should be kept up in a book in each A C R E's office, which should contain a description and plan of all important conductors in the District This record should be a tabular statement showing *(a)* state of soil when inspected, *(b)* date of inspection, *(c)* lightning rods, state of points and connections, *(d)* conductors, and condition, *(e)* earth, condition and amount of resistance in Ohms at each test

24 These instructions are in accordance with the most recent recommendations of the Lightning Research Committee, 1905 Most existing conductors will be found not to fulfil these conditions entirely, nevertheless alteration should only be made in cases of large deviation from the above instructions *

Road Metalling.

1 Road metal will consist either of broken stone, kankar, laterite, or vitrified brick

* A book that may be usefully consulted on this subject is "Modern Lightning Conductors" by Killingworth Hedges M I C E published by Crosby Lockwood & Sons 1905 Price 6s. 6d.

2 When stone is used, it must be hard, tough, and durable, no boulders weighing less than 4 seers must be used

3 Sandstone shall not be used, unless when thoroughly indurated by the action of heat

4 Kankar, laterite, or vitrified brick shall be as tough and heavy as can be procured in the locality A dark blue fracture will generally indicate a good specimen of kankar

5 **New roads, soling.**—For all new roads, except those for very light traffic only, a foundation or "soling" of hand packed rubble, or boulder stone, brickbats, laterite or kankar will be given The soling will be of uniform thickness of from 4 to 6 inches according to the traffic to be carried and all interstices between the rubble or other material will be carefully filled in with chips and earth The soling must not be laid on embankments until they have been thoroughly consolidated The soling will ordinarily be 6 inches wider, on either side, than the proposed width of metal

6 **Preparation and collection of metal** —Road metal before being laid on the road must be perfectly clean and free from any admixture of earth or other foreign matter Stone metal must be broken so that each piece will pass in every direction through a 1½ inch ring, for brick or kankar the ring will be of 3 inches diameter, and for laterite of 4 inches diameter

7 Before stacking, the metal will be screened to remove the fine stuff of half an inch diameter or less

8 The metal will be stacked after screening in long continuous heaps along the side of the road the stacks will be 13 inches high which will be counted as 12 inches only for the purpose of measurement and payment, and of such a section as to give sufficient metal for the corresponding length of road At cross roads a sufficient length of double stacks will be given and care must be taken that the stacks do not *encroach on the cross road The screenings will be collected in heaps* between the stacks and the ditch

9 The metal will be measured for payment in the stacks

10 **Spreading the metal.**—Earthern bunds, puddled on the inner side, and of the height of the metalling, will be made along the edge of the soling, so as to give the exact width to the metal, and to prevent its spreading

11 The metal will be laid with a slope of 1 in 24 from the centre to the edge of the road, the junction of the two slopes being rounded off. In order to secure this, wooden templates of the exact section of the metal before consolidation will be provided, and will be fixed 30 feet apart

12 **Consolidation.**—Rolling should be commenced from the edges and carried on towards the centre of the road

13 The metal must be freely flooded with water during consolidation

14 Templates giving the exact form of the road when completed must be provided, and the surface of the road tested with them during consolidation

15 The metal will be rolled until it is quite hard and compact, so that a light cart passing over it makes no impression on the surface

16 It is very desirable that the consolidation should be completed without the use of any earth or other binding material None should in any case be used with brick, kankar or laterite roads, but with stone metal a small quantity may be necessary In any case not more than enough to form a layer half an inch thick over the surface of the road should be used, it should be broken up fine and mixed with the metal with picks, the shape of the road being carefully tested and preserved

17 When the metal is consolidated the screenings, sufficient to give a layer half an inch thick over the surface, are to be spread, watered and rolled If the screenings are insufficient, clean fine gravel or sand may be added

18 The junction of old and new metalling must be made with a long ramp or slope, which must not be terminated with a feather edge, but buried in the old metal

19 When kankar, laterite or brick metal is used it should be rammed in the first instance with iron rammers, or rolled with only a light roller until partially consolidated Care must be taken that the roller used in all cases is not so heavy as to crush the metal

20 **Berms**—These will be dressed off to a slope of 1 in 40 for a width of from 6 to 12 feet

21 **Remetalling old roads**—The materials and their preparation, collection, spreading and consolidation will be as described for new roads.

22 The surface of the old road will be cleaned, well roughened with pickaxes, all ruts and hollows filled with broken metal, and thoroughly soaked with water before the new metal is laid

23 **General**—The contractor shall use all due precaution for the safety of passengers by placing a barrier across each end of the length of road which is being worked upon

24 This barrier must be substantial, and must in every case receive the approval of the A C R E At night a chowkidar (watchman) must be placed at each barrier to give due warning to persons using the road

25 In the centre of the road, directly across it, and suspended 3 feet over it, will also be fixed a box 5 feet long and 1½ feet square, with transparent sides made of thin cloth facing up and down the road, and within this box will be placed two bright lights The apparatus should be so arranged as to be seen at a distance of 100 yards along the road in both directions on a dark night

26 No traffic will be permitted to pass over a road when under repairs, without the express permission of the A C R E If necessary, to meet the convenience of the public, only one half of the width of a road will be repaired at a time

27 **Patch repairs**—It is most important that all ruts and holes in a road should be repaired as soon as they appear The worn place should be cut out to the full depth of the coat of metal in a rectangular form enclosing the patch with sides parallel to the centre line of the road, the vertical edges being sloped off at an angle of 45°

28 Road metal, as specified above is then to be laid in the holes and covered with a ¼ inch of earth and ½ an inch of screenings, its surface being half its depth above the road It is then to be consolidated with water and heavy iron rammers until the finished surface of the new patch lies perfectly even with the surface of the road

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Well-Sinking.

1 The method employed in sinking wells varies greatly in different places, the opinion of the local native well sinkers should always be invited, as they are generally very expert in their profession

2 The following specifications are given as general ones to be followed in the case of (1) hard soil, (2) sandy soil

3 **Hard Soil** —Rates will include all plant and labour requisite, except where casing is required, the planking for which will be supplied to the contractor who will find the labor for fixing it The contractor is to provide secure means of descending into the well during the progress of the work

4 The excavation for the well will be first marked out to the requisite diameter, which will be 2 feet larger than that of the outside of the steming

5 The excavation will then be commenced and continued vertically downwards until the water level is reached, care being taken to keep it of the same diameter throughout A shaft 4 feet in diameter will then be sunk to ascertain that a water bearing stratum has been reached, which will give a permanent supply of at least 10 feet of water

6 Should any sandy or shaly soil be met with, the sides of the excavation must be cased with planking Rock must be carefully blasted out, the charges used being first approved by the officer in charge of the work

7 The curb will then be placed at the bottom, and will consist of separate thicknesses of sound heart wood of shisham, mulberry, or other hard wood cut to the requisite curve, dove tailed, dowelled and fastened with bolts, straps and trenails It will first be put together on the surface of the ground and after being examined by the officer in charge of the work, it will be taken to pieces, tarred, and lowered down to the bottom of the well, where it will be put together and firmly fixed and levelled

8 Six 1 inch vertical iron rods rising above the curb as high as the depth of water proposed will then be passed through the centre of the curb at equal intervals, and be secured below with nuts to tie down the steming under the water to the curb These tie-rods being secured so as to keep them vertical, the building of the steming on the curb will be commenced round them

9 The steming will be of brickwork or rubble masonry laid in mortar. If of brickwork it will be $1\frac{1}{2}$ feet thick for wells not exceeding 40 feet in depth For deeper wells the steming must be thicker If in rubble masonry, the steming will be 2 feet thick for wells up to 40 feet deep, the stones must be roughly dressed with the hammer to the requisite

shape, and the work executed otherwise as specified for coursed rubble masonry in mortar

10 On the completion of a height of steining equal to the proposed depth of water, a circle of flat bar iron 3" x 1" will be laid on top having holes through which the iron tie rods will pass and against which they will be tightly screwed up, the tops of the screws being rivetted on to the nuts Weep-holes 6" x 3" are to be left at intervals in the steining, as may be directed, for the admission of water

11 The brickwork or masonry will then be allowed to stand until the mortar has set, when the sinking of the cylinder may be commenced, the permission of the officer in charge of the work having first been obtained The earth below the water level will be excavated and the cylinder loaded, care being taken that it descends evenly and vertically

12 When the requisite depth has been obtained the sinking is to cease and steining to be carried up to the top the vacant space round the steining being filled in and thoroughly rammed as work proceeds If it be intended to fix a platform or pump in the well, holes 1 x 6", into the bottom of which 1 inch bolts are to be built, must be left in the steining at the requisite intervals into which beams can be fixed

13 The top portion of steining will be corbelled out to the outside to support the four brick pillars and the portion of the platform which rests over the filling and to prevent any settlement The corbelling will commence 10 courses below the top and will project 2½ inches in each course

14 Round the well will be a platform about 6 feet wide with a brick or terrace floor laid with a slope to a drain round the outside of it, and having a curb round the inside to prevent water flowing back into the well

15 All soil and rubbish must be removed from under the curb until the sole has an even surface

16 **Sandy Soil** —In many localities in India the water bearing sand has small layers of kankar and clay interspersed in it at irregular depths These form very useful platforms on which to rest the curb forming the bottom of the well It is desirable therefore to make a few borings with a sand pump at the site of a proposed well to ascertain whether any of these layers exist at a suitable depth before deciding on the exact spot at which to commence sinking

17 The excavation, laying of curb, and building up of steining will be carried out much as described for hard soil, but below water level the sand will be excavated by a Bull's Dredger, and layers of clay met with by a native "jham"

18 The well should be sunk if possible until the curb rests on a layer of clay, which is well below the water level in the driest season of the year If this layer of clay is only a small mass in the middle of the water bearing strata, it may be pierced in the centre, when the surface of the sand underneath will gradually assume the form of an inverted cone of such an area that the water will come away from it just slowly enough not to take any sand with it The layer of clay forms a platform above this hole, on which the well rests securely, without silting up or giving any trouble If, however, the layer of clay is of large extent it must not be pierced unless it can be ascertained that good water exists below it, or the whole of the supply may be lost

19 When such a layer of clay cannot be found at a reasonable depth the curb must rest in sand, and the steining be supported by friction only In this case any rapid drawing of water will cause the well to silt up, or it may create a hole underneath the curb into which the latter with part of the steining may fall, thus ruining the well

20 On the first signs of a well going crooked during sinking the dredger should be worked on the opposite side of the well to that towards which it is inclined In extreme cases the "jham" may be used instead of the dredger, as it stirs up silt less and allows a deeper hole to be made on one side The well may also be weighted on one side with rails, &c

21 On the completion of the sinking the well will be finished off as specified in paras 12—15

Piling.

1 Piles should be generally driven till they are able to bear 2,000 to 3,000 lbs per square inch with a very small movement, the working load being from 200 to 1,000 lbs. per square inch depending on whether the pile is resting on soft ground or has penetrated soft ground and has its point resting on hard soil

Useful Recipes.

1 **Repairing cracks in terraced roofs—**

(i) 10 seers asphalte, 2½ seers sand, ¾ seer coal tar

Clean out cracks with a brush, and having boiled the materials, apply with a small trowel

(ii) 12 chittacks resin, 8 chittacks sulphur, 1 seer linseed oil

Grind the resin and sulphur fine, mix together, put into the oil, and then boil the whole together

(iii) To stop fine hair cracks in a new roof the following is often very successful —

Spread over the roof a solution of 1 part cement, 1 part cow-dung, 1 part sand—it takes two days to set

2 For compositions for stopping leaks in iron roofs see Director General Military Works Circular No 12 B of 1894

3 **Cleaning Marble** —Mix together one part by weight of country soap with three parts of quicklime and sufficient water to form a paste Lay on with a brush, and when dry, rub down with pumice stone

4 **Putty.**—Take 1 seer whiting, 1 chittack white lead (dry), 6 chittacks raw linseed oil, 2½ tolahs litharge, mix well together and then beat with a wooden mallet until thoroughly incorporated If the putty becomes hard it can be restored by heating it, and working it up again while hot

5 **Glaze for Ceiling Cloths** —Place 6 lbs of Paris whiting in a covered vessel with enough cold water to just cover it Add one quart of double size (made with China glue), mix thoroughly and set in a cool place till it becomes a jelly Dilute for use About 1 lb of the jelly will cover 50 sq feet of ceiling If the above materials are not procurable, the best chalk procurable must be used, ground very fine Rice size may be substituted for glue in the same circumstances about ¼ *lb of rice should make 1 quart of size*

6 **Asphalte Varnish.**—Boil coal tar until it shows a disposition to harden on cooling, this can be ascertained by rubbing a little on a piece of metal Then add about 20 per cent of lump-asphalte, stirring it with the boiling coal tar until all the lumps are melted when it can

be allowed to cool, and kept for use This makes a very bright varnish for sheet metals and is cheap and durable

7 **Varnish for ironwork** —Dissolve, in about 2 lbs of tar-oil, ½ lb of asphaltum, and a like quantity of pounded resin, mix hot in an iron kettle care being taken to prevent any contact with the flame When cold, the varnish is ready for use This varnish is for out-door wood and ironwork

8 **Rendering wood incombustible** —Soak the wood in a strong solution of alum and sulphate of copper About 1 lb of alum and 1 lb of sulphate of copper should be sufficient for 100 gallons of water These substances are dissolved in a small quantity of hot water, then mixed with the water in the vessel in which the wood is to be steeped The timber to be rendered fire proof can be kept under the liquor by stones or any other mode of sinking it All that is required is a water tight vessel of sufficient dimension to hold enough of the liquor to cover the timbers which should be allowed to soak for about four or five days After this, it is taken out and allowed to dry thoroughly before being used A plan of rendering the wood partially fire-proof is to whitewash it two or three times

9 **Glue-melting** —Break the glue into small pieces, and soak from twelve to twenty four hours in cold water, put the glue in the glue pot, fill the outer vessel with water, and apply heat For ordinary purposes it should run freely, and be of the consistency of thin treacle The hotter glue is the more force it will exert in keeping the two parts glued together in all large and long joints the glue should be applied immediately after boiling Glue loses most of its strength by being often melted, that glue therefore, which is newly made, is much preferable to that which has been used When done with add some of the boiling water from the outer vessel to the glue, so as to make it too thin for use Put it away till wanted again and by the time the water in the outer vessel is boiled, the glue in the inner is ready melted and the proper thickness for use Powdered chalk, brick-dust, or saw-dust added to glue will make it hold with more than ordinary firmness

10 **Tarring** —Put as much coal tar as is required on the fire and bring it to the boil Remove from the fire and stir in drop by drop one pint of kerosine oil to each gallon of tar Apply two coats of the mixture with a brush while hot

11 **Good alloy for working models.**—4 parts copper 1 tin, ½ zinc Hardness increased by doubling zinc

12 **Brazing solder.**—Melt brass with ⅛th its weight of zinc Pour out of crucible, cool, and granulate by crushing under a hammer

13 **Colouring walls of a Racquet court.**—Mix for one hundred square feet of walling—

Lamp black 10 chittacks, white lead 6 chittacks, linseed oil 12 chittacks, turpentine 1¼ chittacks

This will lie dead without shine on most walls and will not come off on racquet balls or clothes

14 **Printing Ferrotype plans.**—Put the tracing in the press and then the prepared paper over it Shut the press and place it in the sunlight Expose it for 2 minutes only Then take the press into a dark room and remove the paper from the press and place it in a dish and pour water over it carefully, so as not to leave any portion of the paper dry Wait for 4 or 5 minutes, then again pour water on the paper and again wait Continue this process until the lines stand out clearly, then take the paper from the dish and dry it The press is a solid frame with a hinged glass lid

Specifications of Wrought Iron and Steel work for Bridges, Trusses, &c., and of Cast Iron are laid down in Appendix 30, Schedule C., P. W. D. Code, Vol. II, 6th Edition.

PART II.

WATER-SUPPLY.

WATER-SUPPLY.

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1. **General remarks or preliminary arrangements.**—Water is laid on to Indian Cantonments in one of the following ways —

(a) The Cantonment has a share of the adjacent Municipal supply, sometimes being a partner in the same, at others merely paying a water rate for the quantity consumed

(b) The Cantonment has its own supply quite separate from the Municipality

(c) The Cantonment has its own supply in which, however, the Municipality has a share, sometimes as a partner, at others by paying a water-rate

2 The agreement between the Cantonment and Municipality always involves a lengthy discussion, and is finally ratified with the sanction of Government

3 The supply of water for the initial cost of which provision is made at the expense of Military Works Funds, is limited to the following maximum allowances for the whole population concerned, including those who are not entitled to a free supply —

		Gallons per diem
In the plains,	Europeans—man, woman and child	20
	Natives [illegible] —man, woman and child	[illegible]
	Animals	10
In the hills,	Europeans—man, woman and child	15
	Natives —man, woman and child	5
	Animals	10

Note D [illegible] s Circular No 1 B of 1904.

4 **Source of supply in plains** —The source of supply in the plains nearly always consists of wells sunk either near or in the bed of a river or at the site of an under ground basin The water is generally pumped from these wells into a tank from which it runs to the Canton ment distribution reservoir by gravity Frequently, however, the

supply is taken by gravity to a storage reservoir in Cantonments, from which it is pumped into the distribution reservoir. Occasionally no pumping of any kind is required

5 **In hills.**—In the hills the supply is nearly always collected from streams in higher hills near the Cantonment and run by gravity into a distribution reservoir situated above the station

6 **Number of wells required**—To decide on the number of wells required for a given supply in the plains, the inflow into trial wells sunk at the site proposed for the head works is tested at the driest time of the year, and exhaustive enquiries are made locally as to the lowest known level of the water table in the neighbourhood. The requisite number of wells are then arranged as considered most desirable, generally in one or two lines connected by galleries. Unfortunately very little that is authentic is known about the yield of wells in different soils. Experience has, however, shown that under the steady drain caused by the supply on the underground basin forming its source, the water level at the head works gradually falls, and the supply eventually obtained is far short of that anticipated from the results of the experiments originally made to ascertain the inflow at the wells

It is evident, therefore, that the probable permanent yield of wells forming the head works must always be a subject for prolonged and anxious consideration, as on its correct solution the success of the supply will mainly depend

7 **Springs in hills.**—In the hills this difficulty is of much less importance. The supply from springs is fairly uniform year by year

Here the chief cause of anxiety is the lowness of the springs during the hottest and driest time of the year before the rains break, when the station is usually at its fullest; another trouble is the tendency of hill stations gradually to extend, thus rendering it necessary to take in more springs at the head. The state of the supply at the driest season of the driest year and the power of gradually increasing it, if necessary, are therefore the chief points to be considered in deciding on the yield of a hill water supply

8 The supply from a spring in a hill station should be collected, if possible, at the point where it leaves the hillside, or as near this point as convenient, in a small masonry tank, a design for which is shown in *Plate LXX.*

9 Besides the yield, the purity of the water has to be ascertained before further action can be taken This is done by both chemical and bacteriological examination Rules for collecting water for this examination are given at the end of this chapter, *see* pages 84 and 85

10 **Mains**—The mains of a water supply should be of cast-iron coated inside and out with Dr Angus Smith's composition, the masonry conduits of old supply systems are never likely to be repeated No cast iron pipe of less than 3 inches in diameter should be used, all smaller pipes should be galvanised wrought-iron Turned and bored pipes are preferable when the pipe line is straight, and the ground admits of it, because they are cheaper and easier to lay Where these pipes are used, local conditions will determine the proportion of pipes required with the ordinary wide socket for lead joints In mains it is usually 20 per cent rising to 35 per cent in distribution systems with numerous connections, winding streets, etc In the hills where sharp curves are frequent, spigot and socket pipes are almost essential When pipes are 9 inches in diameter and upwards wrought iron rings shrunk on to the spigot ends of both plain and turned and bored pipes tend greatly to preserve them from breakage during transit In laying plain pipes, these rings can be retained in position

11 **Filters**—In hill supplies filtration is rarely necessary but it is frequently required in the plains The following is the system of filtration adopted at Calcutta where the water is pumped from the Hooghly above Barrackpore, direct into the filter beds —

(*a*) The first or lowest layer of filtering material deposited on, the bottom of the filter consists of a layer of well washed clean gravel or shingle, of the uniform size of nuts or beans, this layer is 6 inches thick at centre and 3 inches thick at sides of tank, its surface being carefully raked to a regular incline

(*b*) The second layer consists of well washed, clean gravel or shingle, of the uniform size of peas to be in a like manner deposited to a depth of 6 inches at the centre, and 3 inches at the side of filter

(*c*) The third layer is composed of well washed clean medium sized sand, intermixed with an equal bulk of clean and

well washed shells, the thickness of this composite layer to be uniformly 9 inches over the whole filter bed

(d) The fourth layer is 10 inches thick, and consists of well washed sand

(e) The fifth and top layer consists of a layer of clean and well washed sand 12 inches thick, laid perfectly smooth and level

At Bangalore an installation of mechanical filters by the Jewell Filtering Company is being tried (1906)

12 **Rate of filtration.**—The rate of filtration on ordinary sand filters should be regulated to a maximum of half a cubic foot per hour per square foot of filtering surface, with a filtering bed about 5 feet thick, this is obtained with a head of 1 to 3 feet depending on the state of freshness of the filtering material

13 **Reservoirs.**—Reservoirs may be of masonry or iron or steel The former are liable to crack and be damaged by earthquakes, the latter to rust The kind to be adopted must be decided by balancing the relative cost and liability to damage in each case, but circular iron or steel tanks are very convenient reservoirs when not too costly They should be so designed that as much of the metal surface as possible can be inspected, so that preservative coats of paint can be applied Reservoirs may be also very suitably constructed of reinforced concrete

14 Both pumping and storage reservoirs should be divided into at least two compartments of nearly equal size, to enable them to be cleaned and repaired periodically without unduly interfering with the supply The neglect of this very obvious precaution has, in some supplies, caused great inconvenience and waste of water

15 **Pumps**—It is a matter for consideration in each case whether it is better to pump the whole quantity of water in one shift of eight hours, or to have smaller engines working two or more shifts, and also whether steam, oil, gas or electrically driven pumps should be used

Where the power required is small and the cost of fuel is high the use of oil engines is indicated

In stations where electrical power is available, it will generally be found practicable to obtain this form of power at such a low price as to make the adoption of electrical pumps desirable When negotiating as to the price to be paid for the electricity, it should be remembered

that the suppliers will certainly be prepared to offer a lower rate, if the pumping is done at a time when their generating station is not fully loaded. Thus an electrical station that supplies most of its power to work mills and little for house lighting, would quote a lower price for a supply at night; while if the conditions of supply were reversed, a cheaper rate would be offered for pumping in the day time.

In indenting for steam pumps no particular type should be specified, but guarantees should be demanded on the form accompanying D. G.'s Circular No. 11 B, dated 15th December 1904, as regards the steam consumption of the engines and the evaporative capacity of the boilers.

The cost of steam pumping plants per horse-power decreases with the size of the plant. The following table gives the approximate cost of different sizes of steam pumps. In column 2 is given the amount which should be allowed for engines and boilers, etc., for each pump-horse-power installed :—

Pump-horse-power of Steam Plant	Total cost per pump-horse-power of plant installed complete, including delivery, erection and putting to work	Remarks
1	2	3
	4[illegible]	
2	12[illegible]	Small and simple plant with short piping and vertical boilers
5	1[illegible]0	High economy plants with all refinement
10	10[illegible]	
20	[illegible]0	
40	50	
80	40	

Note.—The above costs may be reduced frequently to a large extent by the omission of refinements which are normally only justified when fuel is expensive.

The pump horse-power required may be calculated from the formula

$$N = \frac{5 \times H \times Q}{1\,000\,000} \text{ (correct to 1\%)}$$

Where N = pump-horse power

H = head in feet, including static and frictional head

Q = number of gallons to be raised in one hour

16 The working costs vary largely with the price of fuel, the size of the plant, and the number of hours during which the plant is working daily The following table, giving the working cost of steam driven pumps, is taken from actual results and may be used as a guide in rough estimates —

Pump-horse power hours per annum	Total cost in annas per pump horse power per hour.	Pounds of coal per pump horse power per hour	Cost of staff per pump-horse power per hour in annas	Remarks
1	2	3	4	5
	As	Lbs	As	
1,000	16	60	8	This small number of pump horse power hours per year denotes intermittent working short hours small and inefficient pumps, and frequent lighting up
3 000	12	33	6	
3,000	7	23	3	Small pump, working daily eight hours
10 000	5	11	2 75	Medium sized plants, daily eight hours work, with consequent daily lighting up
25 000	3 5	10	2	
50 000	2	6	1	
500,000	7	[illegible]	[illegible]	Large plant working daily for 24 hours

…ote —Column 2 gives the total cost of pumping including fuel supervision labour lubricants engine room stores and minor repairs but not the standing charges (i e interest and depreciation on capital cost).

Column 3 includes all coal or its equivalent in wood used and allows for lighting up ashes clinker and losses in handling The price of coal assumed in column 2 is Rs 15 per ton

Column 4 includes the salary of the engineer in charge and all subordinate staff in the pumping station

17 **Stand-posts** —Each stand post should be provided with a sluice valve, which must be fixed near the stand post Stand posts should be built on a masonry platform about [illegible] feet long by 7 feet wide, if space permits, a mussack or ghurrah stand of suitable pattern should be

provided under the tap The platform should have a good slope to carry all wastage into a convenient drain *See Plate* LXIX

18 **Drainage.**—No water supply system is complete without an efficient drainage scheme, provision should be made for spillage, etc, from stand posts being carried off by road side drains Scour pipes should preferably be carried into some large main drain Drains from stand posts are often carried into gardens, but this system is not recommended as it often leads to a great waste of water

19 **Indents Home and Projects.**—Printed instructions for guidance in the preparation of indents were issued with D G's Circular No 1409B, dated 8th May 1897

These instructions give great assistance regarding details of fittings, etc In preparing indents it is desirable to ask for all specials, valves, stand posts, and fittings, etc, to be supplied with the earliest shipment of the pipes In hill supplies, before these indents can be prepared, it is necessary to have an accurate survey of the pipe line, showing all bends, etc This should be got out on a scale of 20 feet to 1 inch To enable this to be done it is generally necessary to cut out the path for the pipe line along the hill side This work usually forms a preliminary project

20 **Calculations.**—The formulæ and tables to be used in calculations for water supply systems are given on pages 117—126 under the heading "Calculations

21 **Preliminary preparations**—In beginning to lay an extensive length of main pipes, considerable delay, and consequent loss, is often experienced owing to a want of foresight in providing beforehand the necessary men, tools, and material required The following is an enumeration of what it is necessary to provide, varying according to the peculiarities of the District and the extent of the work to be done —

- One or two skilled pipe layers
- A number of labourers provided with picks, shovels, and phowrahs
- A night watchman
- A supply of picks, pick handles and wedges to replace broken ones
- A shear legs or tripod, if the mains are of large diameter
- Blocks, tackle, and ropes or chain and slings

Eight hand spikes for moving the pipes

Four pieces of 3 or 4 inch piping for rolling the pipes in the trench

Four long iron bars and two short ones

Red and white lead paint if turned and bored joints, cotton waste and cleaning material

A supply of spun yarn and pig lead

Two oak blocks, strengthened with hoops to lay against the pipe sockets when driving

Wooden plugs for the various sizes of pipes

A lead pot and two ladles

Chisels and caulking tools

A small pair of bellows

Two large hammers and three small ones

Stock and dies, gas thread, for screwing branches

Portable bench with vice

Tube vice and tongs of sizes

Tube cutters of sizes with spare cutting wheels.

Spirit level and a 12 foot straight edge

Two, or more lanterns for lighting the trench at night

A supply of rammers

Some trestles or bamboos for guarding the open trench at night time or on the road crossings

Planks and small pieces of timber for shoring the trench or for covering portions temporarily

22 The centre line of every trench will be marked out by the Garrison Engineer, or one of his assistants, and the contractor must carefully conform thereto in its excavation In wet porous soil, and where the excavations are deeper than 7 feet, the sides of the trench must be properly shored up The alignment of pipe trenches must be kept as straight and regular as possible

23 On arrival at site the pipes are to be "lined up" as near as circumstances permit to the alignment of trench they are to occupy The pipes are to be unloaded from the carts with ends touching, sockets in all cases facing the direction from which the water will eventually flow, every twentieth pipe being duplicated to allow for joints, etc At road crossings, etc., the number of pipes required will be ranged conveniently,

half on either side of the space to be crossed. In the case of pipes less than 4 inches diameter they may be placed at suitable intervals in small stacks of not more than 25 pipes

24 **Excavation of trench** —The bed of the trench will be evenly and truly dressed throughout from change of grade to change of grade, to obviate any subsequent rectification, by packing or filling under the pipe. The "spoil" should be thrown out on the side of the trench opposite to that on which the pipes have been collected, and when road metal has to be removed and replaced, it should be separately deposited on one side of the trench, ready for subsequent re use. All road crossings to be excavated half at a time the second half being commenced after the first has been refilled over pipes laid, and opened for traffic

25 In cases where blasting is necessary, the rock should be removed to a depth of at least 6 inches below formation level, and the bed of the trench made up with sand or thoroughly rammed earth before pipes are laid. In light or loamy soil the bottoms of trenches are to be well rammed before pipe laying is commenced. Any holes or unsound places met with during excavation are to be carefully cut out and refilled with sand or well consolidated soil before pipes are laid

26 In crossing marshy sites the grade can be preserved by sinking slabs of stone or slate vertically through the soft soil (if of no great depth) to a firm foundation and adjusting their tops as required a concave notch forming a seat for the pipe

27 The minimum depth of trenches is to be 2 feet 6 inches plus the diameter of the pipe to be laid the minimum widths at top being as under —

For pipes 3 to 6 inches—trench 18 inches wide
" " 7 to 10 " , 24 , "
" " 12 to 20 " " 36 , "

28 Local conditions will in all cases determine the best relative rates of progress of excavating and pipe laying gangs, as a general rule it should be sufficient for the former to keep from one to two full day's work ahead of the latter

29 When a trench is left open at night a chowkidar must be left in charge, and a good oil lamp in a clean lantern preferably furnished with red panes, must be placed at each end and also at intervals of 50

feet along the trench If necessary a bamboo fence must be put up to prevent danger to passengers

30 The bottom of the trench should be carefully graded, grade pegs spaced 50 to 200 feet apart being placed along the pipe line clear of the edge of the trench with distinguishing marks at every point where the grade changes The bottom of the trench will then be graded to a fixed vertical distance below these pegs by means of pieces of bamboo, of length equal to this distance, and boning rods, which are given to coolies and mates respectively The grading of the bottom of trenches must be carefully checked by the officer in charge of the work before pipe laying is commenced

31 **Pipe-laying in general** —All pipes are to be laid with sockets facing the direction from which water is to flow Every pipe must be carefully sounded and examined before laying, for cracks or flaws that may so far have escaped detection Each pipe must then be cleaned internally, for which purpose old sacking firmly bound to the end of a long bamboo to form a mop may be used Pipes of small diameter should be up-ended, and all dust, &c, shaken out after the mop has been used

32 Cracked pipes are to be cut with diamond pointed steel chisels, the cut to be made at least 6 inches beyond the visible extremity of the crack and on a line girdling the pipe at right angles to its longitudinal axis

33 Work should generally be commenced at the extremity of the line furthest from the source of supply, or from a valve, branch, or special, forming a break in the line, and in the case of leading distribution mains, from the absolute end if possible This procedure lessens the number of subsequent connections, saves collars, and obviates unnecessary cutting of pipes

34 Lead required for jointing should always be supplied departmentally, otherwise as it is an expensive item, contractors will starve the joints It can be obtained from the arsenals, the lead of the snider bullet being very suitable That of the modern bullet is too hard, it can, however be satisfactorily blended with blue virgin lead in any proportion found most desirable on trial Lead from Commissariat tea chests can sometimes be obtained, it is very soft

35 The open end of the last pipe laid is to be securely closed on ceasing work for the day with a strong wooden plug fitting the socket

of the pipe, around which it is securely fastened with a chain attachment and padlock.

36 **Pipes in use.**—The pipes in general use are —

(*a*) Cast iron pipes plain, spigot and socket

(*b*) Cast iron pipes turned and bored

(*c*) Galvanised wrought iron pipes with screw and socket joints, steam and water quality

(*d*) Mild steel pipes for very great heads

Cast iron pipes are not very satisfactory for anything over 250 feet head, for although the market pipe is usually tested to 300 feet, it is difficult to make a lead joint to work under this head

The galvanised wrought iron pipes supplied through the Secretary of State are of such excellent quality that up to 2 inches in diameter they work safely under a head of 1,000 feet Those supplied by Indian Firms can only be relied on for heads under 300 feet

Special galvanised wrought iron pipes up to 4 inches diameter capable of working safely under a head of 800 feet are easily obtainable from England on indent

37 **Laying cast-iron pipes with plain, spigot and socket joints.**—The trench will be filled with a little soft earth free from stones, which will be shovelled in gradually, one heap being placed at the centre of each pipe On these heaps the pipes are balanced, and they can then be easily graded and lined by scraping the earth away either by hand or with shovels For lowering the pipes into ordinary trenches ropes are necessary for 7 inch to 20 inch diameters, for larger sizes tackle is required

38 The spigot end of the pipe to be jointed is first truly centered in its socket, steel wedges being used for this purpose The socket is then caulked with white spun yarn or gasket, of which sufficient laps must be given to leave, after the yarn has been evenly and solidly packed to the shoulder of the socket with the yarning iron, the correct depth specified for the lead, from the face of the socket This depth is to be—

For pipes	$2\frac{1}{2}$ to 4 inch,	1 inch
" "	5 to 8 "	$1\frac{1}{4}$ "
" "	9 to 12 "	$1\frac{1}{2}$ "
" "	14 to 18 "	$1\frac{3}{4}$ "
" "	20 to 24 "	... 2 "

The laps of yarn used, which will never be less than three, must be all rather longer than the circumference of the socket, no make-up pieces are to be allowed. The laps are to be twisted into a rope of uniform thickness, and caulked in that form into the socket.

39. The pipes are then to be again carefully graded and the slope of each pipe tested with a hand level. The pipes which are now ready for leading are each supported in the centre for about two-thirds of their length on a flattened mound of earth, while at each joint is a small pit which is required for leading and caulking.

40. To lead the joints, first clear them of earth and pebbles. Then make a wrapper of spun yarn worked up with clay having the consistency of putty. This should be about 3 inches wide and ¾ inch thick and 4 inches longer than the diameter of the joint. Wrap this round the joint with the overlap on top, and make a hole in it to admit of the molten lead being poured in. This must be thoroughly liquid, and the ladle for pouring it into the joint should hold a little more than is required for one joint. The filling should be one operation and the lead should be poured in quickly. Then strip the wrapper off and use it on the next joint and so on.

41. When a section of a few hundred feet is leaded, the caulking should be put in hand. Each gang of caulkers should consist of at least four blacksmiths, and for large diameters the numbers should be increased. One of these must be a good smith. Place the men in line, the worst man in front, and let them proceed to caulk a joint each with a caulking iron and blacksmith's hammer. Every 15 minutes move the gang on one joint, thus each joint receives an hour's caulking and is worked on by all four smiths. The lower portion of the joint requires especial attention and supervision.

42. Should it be necessary to work quickly, many sections can be laid at the same time. Where their ends meet they may be joined by a sleeve joint, or by simply cutting the final pipe to length, when the spigot may be slipped into its socket by lifting one or two of the pipes laid buckling on either side of the last joint to be laid.

43. **Laying cast-iron pipes with turned and bored joints.**—The first layer of soft earth should be completely filled in and rammed in stony rocky soil before placing the pipes in the trench which must be quite free from windings. The turned fillet at spigot end

and surface of the turned ring within the socket of each pipe are to be thoroughly cleaned and polished. This can be satisfactorily done by coolies using soft brick, sand, old sacking, and buckets of water. The surfaces so polished are then to be thoroughly washed, and the spigot end and socket ring are again wiped round with a clean wet cloth at the moment of inserting the former into the latter.

44. After the first pipe has been placed in position the second is lowered and the spigot is carefully guided into the socket of the first by the ganger in the trench, who at the same time adjusts the pipe as regards alignment and grade. The next pipe is then brought up and used as a ram* to drive the preceding pipe home being swung on a rope sling by coolies, standing in equal rows on either side of the trench.

These men lean forward head to shoulder and lift and swing together. The ram is guided by a second man in the trench who grasps the socket end and assists in keeping the pipe straight and so delivering the blows fairly and evenly. The ganger meanwhile sits astride the last socket and closely watches and directs the driving home of the spigot therein.

This operation must be carried out with great care, particularly with pipes of small calibre, the sockets of which are apt to split if the driving home be over done. About four or five blows of the ram are generally sufficient for pipes up to 10 inches diameter. For those from 10 to 20 inches (beyond which T and B pipes are now rarely used) a pipe of 10 to 12 inches diameter makes an efficient ram. The use of a wooden buffer to deaden the blow is generally advocated. These blocks break up rapidly and with skilled pipe layers they are not necessary.

45. No external joint of any kind whatsoever will be given to turned and bored pipes, but at points difficult of subsequent access, such as under railways, drains, etc., the joints should be leaded as an additional precaution.

46. In laying long lengths of turned and bored mains, lead joints should be given at intervals of about 100 yards, to allow for expansion and contraction. If plain pipes be not available, a turned spigot may be cut off at each point for this purpose. The laying of turned and bored pipes reversely, i.e., driving sockets on to spigots is prohibited.

* The ram is sometimes used by hauling a pipe backwards and forwards on rollers laid upon the trench bottom. It is found, however, that progress is less by 30 per cent. than with a swinging ram.

47 **Laying galvanised wrought-iron pipes with screw and socket joints** —All piping when below ground will be laid at a minimum depth of 18 inches below the surface All screwed connections to be taper threaded, and the use of red or white lead, or any composition of any kind whatsoever in making joints is to be discouraged No undulations are permitted, the piping must be truly laid to a grade either rising or falling or dead level as may be ordered In fixing tees, branches, etc, care must be taken that on no account is a branch pipe permitted to encroach, by projecting upon the waterway of the pipe from which it springs

48 In ordinary pipe lines hardly any bends are required, and the pipe trench should be cut winding throughout except in cases where quick bends are required The pipes when laid spring into quite sharp curves without any damage, and a good 14 foot steam-quality pipe can be bent in its length by means of crowbars to take a change of direction of 15° This should not be attempted at joints or screw threads may part

49 The joint is made by screwing the end of the pipe to be laid into the socket of the pipe last laid To do this use four pipe tongs, two on each pipe worked in opposite directions care must be taken to prevent the pipe already laid turning during the operation or tee pipes will get out of level The end of the pipe last laid is supported above ground by a crowbar laid across the trench, thus facilitating the use of the tongs.

50 In the hills the pipes should be laid winding in the trench to allow for contraction when the cold water is run in For the same reason the pipe on the inside of a curve should not bear against the rock side of the trench

51 Sections of piping may be joined by a screw collar or coupling, which is run up the end of one pipe, and on the other being brought opposite, down the end of this pipe until it grasps both equally

52 When the piping is more than 2 inches in diameter it cannot be bent to any great extent and it must be laid in the bottom of the trench

53 **Laying mild steel pipes** —For great heads and large diameters mild steel tubes are used They are lap-welded and have special joints.

At Murree, steel rings carefully turned, were shrunk on to the ends of the pipes, one end being tongued and the other grooved A

rubber washer was placed in the groove and the tongue of the next pipe was then fitted into it, and heavy cast iron collars fixed behind the steel rings. The joint was then secured by screwing up six cross bolts passing through holes in the cast iron collars.

54 To provide for contraction and expansion, sleeves made from locomotive buffer tubes were placed over the ends of tubes after the steel rings had been removed. A deep lead filling was run in and caulked. To prevent this blowing out, segments of steel were placed round the tubes, bearing against the lead at the ends of the sleeve. Over these segments the ordinary cast iron collars were placed and drawn together by the longitudinal bolts until the segments pressed firmly against the lead at either end of the sleeve. This joint worked well under a head of 1,400 feet. The idea was that contraction and expansion took place by the steel tubes sliding in the lead jackets.

55 **Testing and filling in—General.**—When the joints have been completed turn on the water and test them. This may be done by closing cross sluice valves and thus producing runs. This should be continued in each section for two days. Any leaking joints should be made good by leading and extra caulking.

56 After the pipes have been tested the trenches are to be filled in with earth laid in 6 inch layers watered and carefully rammed, preferably with wooden rammers. Street metalling is to be restored and the surface neatly dressed to a proper level. All extra earth and rubbish is to be removed forthwith by the contractor on the completion of the filling in of each trench. Great care must be taken that the space underneath the pipes is properly filled in and that the sockets are adequately supported. Any sinkage from defective laying within three months of completion will be made good by the contractor at his own expense.

57 **Joints in flanged pipes.**—In laying these, the faces of flanges or raised strips as the case may be must be first thoroughly cleaned and in bolting up after the specified "insertion" has been placed in position, care must be taken to tighten the flange bolts gradually and evenly all round. When washers of rubber or other material are used, they must be held in position by loops of thin twine through the bolt holes before the flanges are brought together, care being taken that the washer is not allowed to encroach in the least on the bore of the

pipe. Chalk rubbed upon the faced strips of a flanged joint before inserting the washer facilitates subsequent removal, by preventing the latter from adhering to the metal faces. Leaks through bolt holes of flanged joints can be stopped by the insertion of lead washers under the head or nut of bolt, as may be required.

58. **Setting of valves.**—The covers and glands of all valves are to be removed, packing adjusted, spindles and gates examined, and the whole refitted in face and *perfect order, before being sent to site.* In setting, the valve must be carefully adjusted as nearly vertical as possible in both directions, before the lead joints of the connecting tail pieces are made. The specification already given for flanged joints applies equally to those of all valves.

59. **Surface boxes over valves.**—The top of the surface box should as a rule be flush with the roadway. Cast iron surface boxes of the ordinary small conical type will be fixed as follows:—the trench filling is first thoroughly consolidated up to the level of the lower flange of the valve cover, and upon this is built a small encircling half brick dry wall, upon which rests the base of the surface box, the depth of the brickwork being such as to bring the top of the surface box level with the roadway. The packing and consolidation of the road metal round the box completes the operation. In the case of large valves on mains, to which access is considered desirable, pits constructed of pucka masonry with cast iron flap covers will be necessary. These pits should be sufficiently large to enable a man to work round the valve.

60. **Distribution system.**—For the distribution system within station limits where the mains, especially in the plains, generally follow well graded roads, it will be unnecessary in most cases to do more than lay the pipes in trenches of uniform depth, in accordance with those grades, taking care to insert an air valve at every summit where there is no stand post to act as such. Every case of doubt or difficulty that presents itself will be settled on the spot with the level as work proceeds, and the grades of each day's work are to be checked with the spirit level before the trenches are filled in.

61. It is very necessary that as pipes, etc., are laid, their exact positions should be clearly shown weekly on the record plans. The absence of such plans in the older supply systems has led to great inconvenience at times.

62 The following Table gives the weight of lead required for jointing cast iron mains, on the assumption that up to 8 inches diameter the lead is ⅜ inch thick, and beyond that ½ inch thick When, however, the reduced depths, specified in para 38, which are sufficient up to heads of 300 feet, are used, the weights will be proportionately less —

Diameter of the pipe in inches	Weight of lead in pounds	Depth of lead in inches	Diameter of the pipe in inches	Weight of lead in pounds	Depth of lead in inches
1½	1¼	1⅜	11	16½	2¼
2	1¾	1½	12	18¾	2⅜
2½	2¼	1½	13	21	2⅜
3	2¾	1⅝	14	23¼	2⅜
4	4	1¾	15	26	2½
5	5½	1¾	16	28½	2½
6	7	2	17	31	2½
7	8¾	2	18	32¾	2⅝
8	10½	2¼	19	34	2⅝
9	12½	2¼	20	[illegible]	2⅞
10	14½	2¼	24	48	3

63 **Dr. Angus Smith's Solution and method of applying it to pipes**—It is anything but easy to put on this solution at site of work but as it may have to be done at times, a description of the process to be followed is given below The solution is an admixture of pitch and linseed oil The pitch is made from coal tar distilled until the naphtha is entirely removed and the material deodorised and until the pitch is of the consistency of wax, 5 or 6 per cent of linseed oil may then be added Pitch which becomes hard and brittle when cold will not answer for this purpose

64 Every pipe must be thoroughly dressed and freed from the sand which clings to the iron in the moulds, hard brushes being used in finishing to remove the loose dust All rust must also be removed If the pipe cannot be dipped directly after being cleaned the surface must be oiled with linseed oil to preserve it until it is ready to be coated No pipe is to be dipped after rust has set in

65 Pitch of the proper quality having been obtained, it must be carefully heated in a suitable vessel to a temperature of 300° Fahrenheit and must be maintained at not less than this temperature during the time of dipping The material will thicken and deteriorate after a

number of pipes have been dipped, fresh pitch must therefore frequently be added, and occasionally the vessel must be entirely emptied of its old contents and refilled with fresh ingredients. The refuse will be hard and brittle, like common pitch.

66. Every pipe must attain a temperature of 300° Fahrenheit before removal from the pan. When this temperature is reached it may then be slowly taken out and laid upon skids to dry.

67. When coating turned and bored pipes the machined portions are coated with loam intermixed with water to form a paste which is allowed to dry before immersion, the loam breaks off when the pipe is cold.

68. The cost of maintenance of water supplies varies considerably in different stations, depending on—

(a) Cost of fuel.
(b) Cost of labour and materials.
(c) Length of line and number of taps.
(d) The construction and position of reservoirs.
(e) The age and description of the machinery.

69. For a period of two years after completion, the whole line of main should be carefully patrolled daily by chowkidars, and any subsidence of the ground, signs of leakage, etc., at once reported; after this period the main lines need not be inspected more than once a week. The whole area supplied by water should be divided into convenient divisions, each division being placed in charge of a chowkidar or "Inspector." This man's duties are—

To inspect every tap and line of main in his district daily.
To exchange taps found defective.
To see that stand posts and platforms are kept clean.
To open the scour valves periodically.
To report breakages, or ill usage of taps and waste of water.
To oil the valve spindles and to see that the valves are in working order.
He should report to the office at least once daily.
He should know the position of every valve in his district and to what extent the closing or opening of the valves affects the general distribution; also how in case of fire to arrange the valves so that the whole supply of water can be directed to a certain locality.

70 By judiciously transferring these Inspectors from one district to another, they gradually learn the positions of the taps, valves, mains, etc, in the whole station

71 Each stand post and tap should be numbered and a map carefully kept up to date should be maintained, showing the positions and numbers of stand posts, taps and valves Copies, preferably ferrotypes, of this map, should be provided for the Cantonment Magistrate, Deputy Commissioner, and Staff Officers or others, who may have to refer in correspondence to the water supply

72 Stand posts require repainting every third year To avoid obliteration of the numbers and the expense of re numbering, it is advisable to have the numbers cast on stand post covers by the makers

73 When carrying out the distribution scheme of a water works, careful record on plans or maps should be kept of the position of every pipe, valve, etc, showing sizes of pipes depths below ground level, and the accurate positions of sluice valves air valves, hydrants, etc with reference to some permanent building Neglect of this precaution causes endless trouble sometimes, as after a lapse of years, with frequent changes of officers and subordinates valves and sometimes long lengths of pipe are apt to be "lost

74 In water heavily charged with lime, the gun metal faces and spindles of sluice valves speedily become coated, and the valve becomes unworkable and has to be removed to be cleaned To avoid this valves should be regularly worked once a month Meters too, frequently are rendered unworkable from this cause and require periodical cleaning It is advisable to have one or two spare meters in store, and where a number are in use, a set of tools for repairing, and duplicate fittings should be kept in stock In the working of and repairs to valves, taps, etc, the use of Neats foot oil and tallow should be avoided as far as possible, especially in localities inhabited by Hindus The use of leather washers sometimes causes trouble unless the natives are assured that the leather is "goat skin

75 Air valves should be regularly tested to ascertain if they are in working order

76 Regulating ferrules are preferable to meters where the supply is small and constant

77 The "head of water at any given point is easily found by fixing

a union or coupling an ordinary steam gauge on the tap; the pres shown × 2 307 = head in feet

78 Registers, posted daily, should be carefully maintained to show Quantity of water in reservoirs, received from head works, pump used, and so on

Diagrams showing the consumption, etc, posted monthly or wee are very useful for easy reference

79 Where pumping machinery is used, registers should be kept show the boiler and engine in use, the quantity of water raised an fuel, lubricants, waste and other stores used These are necess to enable the return required by Director General's Circular Let No 281 E of 1st June 1905 to be filled in

80 The recurring charges incurred in connection with water supp are divided into Maintenance Charges and Working Charges, both del able to M W Estimates

(i) *Maintenance charges* include expenditure on—

(a) the repair and renewal of such works as buildings, ma tanks, stand posts, connections and fittings to Governm buildings

(b) quarters for establishment employed on the construction maintenance of a water supply,

(c) the repair and renewal of machinery,

(d) the pay of establishment engaged in supervision and care plant or buildings

(ii) *Working charges* comprise expenditure on—

(a) payments for water supplied by municipalities or oth local bodies,

(b) pumping and working expenses, including fuel, oil, sand gravel, etc, for filtering purposes, shelter and keep animals employed on the supply of water,

(c) pay, housing and all incidental charges in connection wi establishment, clerical or otherwise, engaged in the super sion and check of the distribution of water, and in the coll tion of water rates or taxes, and

(d) the supply, fixing and repairs of meters (except those mains which form an integral part of the water supply in tallation), and other means of controlling the distributi

or of measuring the supply of water, the pay and incidental expenses connected with the establishment engaged in the maintenance, check and reading of meters or similar contrivances

81 Orders regarding the administration of water supplies are contained in Director General's Circulars Nos 13 B of 1902, 17 B of 1903, 26 B of 1903, 2 B of 1904, 25 B of 1904, and 18 B, 42 B of 1906

82 **Books of reference** —*The following books are recommended* on this subject, and they should be consulted when a large project is under preparation —

No	Name	Price
1	Practical Hydraulics 1889 by Thomas Box	Rs 3 15 0
2	Treatise on Hydraulic and Water-supply Engineering 1896 by J T Fanning C E	25 Shillings
3	Water-supply of Towns, 1894 by W K Burton	25 „
4	Water supply of Barracks and Cantonments 1896 by Major Scott Moncrieff, R E	10s [illegible]
5	Water Pipe Discharge Diagrams 1891, by E B Taylor, C E	
6	Manual of Hydraulics 1894 2nd Edition by H D Love	Rs 2-8 0
7	Notes on Indents for Pipes and other stores for water works	

a union or coupling an ordinary steam gauge on the tap; the pressure shown × 2 307 = head in feet

78 Registers, posted daily, should be carefully maintained to show —

Quantity of water in reservoirs, received from head works, pumped, used, and so on

Diagrams showing the consumption, etc, posted monthly or weekly, are very useful for easy reference

79 Where pumping machinery is used, registers should be kept to show the boiler and engine in use, the quantity of water raised and of fuel, lubricants, waste and other stores used These are necessary to enable the return required by Director General's Circular Letter No. 281 E of 1st June 1905 to be filled in

80 The recurring charges incurred in connection with water supplies are divided into Maintenance Charges and Working Charges, both debitable to M W Estimates

(i) *Maintenance charges* include expenditure on—

(a) the repair and renewal of such works as buildings, mains, tanks, stand posts, connections and fittings to Government buildings,

(b) quarters for establishment employed on the construction or maintenance of a water supply,

(c) the repair and renewal of machinery,

(d) the pay of establishment engaged in supervision and care of plant or buildings

(ii) *Working charges* comprise expenditure on—

(a) payments for water supplied by municipalities or other local bodies,

(b) pumping and working expenses, including fuel, oil, sand or gravel, etc, for filtering purposes, shelter and keep of animals employed on the supply of water,

(c) pay, housing and all incidental charges in connection with establishment, clerical or otherwise, engaged in the supervision and check of the distribution of water, and in the collection of water rates or taxes, and

(d) the supply, fixing and repairs of meters (except those on mains which form an integral part of the water supply installation), and other means of controlling the distribution

9 Pending examination, water samples should be kept in a dark and cool place

10 The fullest information ought always to be furnished with the sample, the following being the most important particulars —

(a) Source, whether from tank or cistern main or house pipe, spring river, stream, lake or well

(b) If a well, depth, diameter, strata through which sunk, whether imperviously steined and how far down it is so protected Particulars as to whether the well is open or covered, and what arrangements exist for withdrawing the water

(c) Possibilities of impurities reaching the water, notably distance of well from midlens, manure heaps, cesspools, stables, etc, etc, proximity of cultivated land

(d) If a surface water, or rain water, nature of the collecting surface and conditions of storage

(e) Meteorological conditions, with reference to recent drought or excessive rainfall

(f) A statement of the existence of any disease supposed to be connected with the water supply, or any other special reasons for requiring analysis

11 Any further information that can be obtained will always be useful

12 Each bottle should be distinctly labelled, so as to correspond with the official letter or invoice

13 For bacterial examination the sample should always be taken by the officer making the examination, as many technical details have to be observed in its collection

PART III.

FORMS

OF

CALCULATIONS

TO BE ADOPTED

IN ORDER TO INSURE UNIFORMITY.

CALCULATIONS.

1 Calculations, showing the weight borne on foundations, the scantlings of the principal rafters, and of the common rafters, purlins and battens in all timber roofs, also of the strap and bolt at the foot of the principal rafter, and of the tie-beam, *where the latter has to carry a ceiling*, the dimensions of *all* the parts of a steel roof truss, the scantlings of all floor joists, whether of wood or steel, and of all steel girders should, when necessary, accompany every Project The above is a general enumeration of the calculations necessary in the preparation of projects, but other cases may occur in which it may be necessary for the A C R E to submit calculations, *e g*, for the strength of retaining walls of bridges in Cantonment roads, etc, etc

2 Calculations should be as concise as possible, consistently with giving all that is really necessary, *e g*, in the calculations for the timbers in a roof truss, it will only be necessary to work out the scantling of the principal rafter, as all the other portions will be found to show by calculation a smaller scantling than can be adopted practically The scantling of the principal rafter being determined, the tie-beam and straining beam (where such exists) may be constructed of the same scantling, and in most cases all the other portions square in section, with the side of the square equal to the smaller dimension of the principal rafter, but, where the tie-beam is to carry a ceiling, a special calculation for it will be necessary In the case of a steel roof, however, calculations of all the parts should be given, as in this case they can generally be constructed *practically* of the dimensions calculated.

3 Examples are given further on of the calculations most usually required A reference to these examples will illustrate in detail the instructions given above, and to insure facility of reference, all calculations should be submitted in the form given therein, the figures occupying the positions which they occupy in the examples

4 *All beams, timbers, etc*, are to be calculated by *both* the Formulæ for Transverse Stress, *and* for Deflection, the larger result in each case being invariably adopted

5 In calculating the scantlings of *battens, common rafters*, and *purlins*, the vertical weight of the roof covering is to be reduced to normal pressure, by multiplying the actual weight by the cosine of the angle

of pitch of the roof, to this should be added allowance for work people also reduced to normal or the normal wind pressure, the weight of the piece itself, and that of the pieces over it, the sum of the whole being expressed as W in the formulæ The calculation should then be made by the formulæ for *Transverse Stress* and *Deflection*

6 A reference to the examples will show precisely the method which should be adopted in each of the above cases

7 A sketch of the truss, drawn in simple lines to a convenient scale, should accompany the calculation of stresses on a roof, the span of the truss being taken from the centre of the walls on each side The common rafters may be taken as of the same length as the principal rafters The adoption of this method will insure the same dimensions being measured off by every one, both in making, and in examining, calculations

8 If the principal rafter, or any member of a truss, is subject to a transverse as well as to a direct stress, the compressive element of the bending stress must be added to the direct compression In the case of wooden beams a depth should be assumed and the breadths required to meet the transverse and direct loads respectively should be added together, *vide* calculations for the principal rafter in Example IV

9 Floor girders, the ends of which are built into the walls, may be treated as fixed beams

Purlins which are in continuous lengths, or firmly connected by fish plates may also be treated as fixed beams

10 When trusses are far apart, and rolled steel purlins used, it is necessary to calculate whether they are stiff enough to resist the stress acting parallel to the roof

11 In working with logarithms, quantities should be taken out to the number of places of decimals which corresponds to the number of figures to which the logarithm tables are worked out For instance, taking Chambers's Logarithm Tables, which are worked out to five figures, numbers above ten thousand need not generally be worked out to decimals at all, thousands should usually be worked out to one, and hundreds to two places of decimals Generally it will be unnecessary to work out numbers to more than two places of decimals.

12 Tables of safe working loads on rolled steel beams of British Standard sections, worked out by the formulæ on page 111 have been issued, and may be used

Notation.

The following Notation should be strictly followed in making calculations —

i *Forces*	P = Any force or stress, in lbs W = Uniformly distributed load on any given length or surface, in lbs w = Any specified weight other than W, in lbs
ii *Strength for Materials (Constants),*	c = Safe crushing stress per square inch of section, in lbs s = Safe shearing stress per square inch of section, in lbs t = Safe tensile stress per square inch of section, in lbs
iii *Constants for Timber,*	p for deflection, r for transverse stress, } *see* Table V, in lbs
iv *Dimensions,*	b, b_1, b_2, &c = Breadths of beams, &c, in inches d, d_1, d_2, &c, = Depths of beams, &c, in inches h = Least sectional dimension in inches (*see* Formulæ V) l = Unsupported length of beam, girder, etc, in inches L = Unsupported length of beam, girder, etc, in feet S = Any sectional area in square inches δ = deflection of beam, girder, etc, in inches
v *Calculations by Moments of Inertia,*	I Moment of Inertia, (*see* Table VI) μ = " Resistance (do) x Distance of neutral axis from tension flange, (*see* Table VI), in inches

Formulæ.

In the following formulæ it has been assumed, that—

(i) In beams under a permanent dead load—

$\delta = \frac{L}{40}$ is the maximum safe deflection, and that in transverse stress a factor of safety of 10 should be allowed

(ii) In beams under a partly permanent and partly occasional load—

$\delta = \frac{L}{20}$ is the maximum safe deflection, and that in transverse stress a factor of safety of 6 should be allowed

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General Formulæ for rectangular wooden beams planks, etc, uniformly loaded, supported at both ends

I For Deflection—

With permanent load, $d = \sqrt[3]{\frac{25\ L^2 \times W}{b \times p}}$

With part permanent and part occasional load, $d = \sqrt[3]{\frac{25\ L^2 \times W}{2 \times b \times p}}$

II For Transverse stress—

With permanent load, $d = \sqrt[2]{\frac{10 \times L \times W}{2 \times r \times b}}$

With part permanent and part occasional load $d = \sqrt[2]{\frac{6 \times L \times W}{2 \times r \times b}}$

III By substituting the values of p and r given in Table V in the above formulæ the following simple formulæ, which are recommended for general use in practice, are derived —

Nature of timber used	Deflection $bd^3 =$		Transverse Stress $bd^2 =$	
	Permanent load.	Part permanent and part occasional load	Permanent load	Part permanent and part occasional load
Sal	$\frac{WL^2}{165}$	$\frac{WL^2}{330}$	$\frac{WL}{150}$	$\frac{WL}{250}$
Teak or venteak	$\frac{WL^2}{160}$	$\frac{WL^2}{320}$	$\frac{WL}{130}$	$\frac{WL}{215}$
Deodar, bair or chir*	$\frac{WL^2}{125}$	$\frac{WL^2}{250}$	$\frac{WL}{90}$	$\frac{WL}{160}$
Honnay or vengay	$\frac{WL^2}{165}$	$\frac{WL^2}{330}$	$\frac{WL}{140}$	$\frac{WL}{205}$

* Note —Chir wood should only be used for interior work

For values of bd^2 and bd^3 for different scantlings, see Tables VII and VIII, pages 102—5

In some cases the calculations for permanent load only give a larger section than that for part permanent and part occasional load In such cases the larger section should be adopted

In each of the following cases the values given in the above Tables for bd^2 and bd^3 must be multiplied by the constant given below to give their correct value for the section required

(1) Beam supported at both ends loaded in centre, multiply by 2

(2) „ fixed at one end loaded uniformly, „ „ 4

(3) „ „ „ „ „ at the other, „ „ 8

(4) „ „ both ends loaded uniformly, „ „ $\frac{2}{3}$

(5) „ „ „ „ „ in centre, „ „ 1

(For other cases see R E Aide Memoire, Vol I, para 161 Moments of Flexure)

IV Formulæ for any substance under tensile or shearing stress—

Where

$S =$ *smallest* section, in square inches

$P = S \times t$ (Tensile stress)

$P = S \times s$ (Shearing stress)

V Formulæ for crushing stress on timber struts—

$P =$ total pressure on strut, in lbs

$S =$ sectional area of strut, in square inches

When l is less than $8h$, $P = cS$, (i)

„ l lies between $8h$ and $12h$, $P = \frac{5}{8} cS$, (ii)

„ „ „ $12h$ and $24h$, $P = \frac{1}{2} cS$, (iii)

„ „ „ $24h$ and $36h$, $P = \frac{1}{4} cS$, (iv)

„ „ „ $36h$ and $48h$, $P = \frac{1}{6} cS$, (v)

VI For steel or iron struts, Table XII on page 115 calculated by Fidler's formula should be used —

Formulæ for calculating the various stresses in King post and Queen post trusses

Here W = Weight of roof covering, (Table III)
- " common rafters,
- " purlin (or purlins),
- " principal rafter,
- " steel work, (Table I),

Allowance for work people or normal pressure of wind, (page 96),

} borne vertically by *one* principal rafter, in lbs

$w = \frac{5}{8}$ (tie beam + ceiling on it)
two struts,
one King post, or (two Queen posts + straining beam + straining sill)

} in lbs

θ = inclination of roof to the horizon

VII For a King post truss—

(*a*) Thrust on heel of principal rafter, $= \left(\frac{13}{16}W + \frac{w}{2}\right)$ cosec θ *

(*b*) Tension on tie beam, $= \left(\frac{13}{16}W + \frac{w}{2}\right)$ cot θ

(*c*) Thrust on strut, $= \frac{5}{16}W$ cosec θ

(*d*) Tension on King post, $= \frac{5}{8}W + w$

VIII For a Queen post truss—

(*a*) Thrust on heel of principal rafter, $= \left(\frac{5}{6}W + \frac{w}{2}\right)$ cosec θ

(*b*) Tension on tie-beam, $= \left(\frac{5}{6}W + \frac{w}{2}\right)$ cot θ

(*c*) Thrust on strut, $= \frac{W}{6}$ cosec θ

(*d*) Tension on Queen post, $= \frac{W}{3} + \frac{w}{2}$

(*e*) Thrust on straining beam, $= \left(\frac{2}{3}W + \frac{w}{2}\right)$ cot θ

(*f*) Thrust on straining-sill, $= \frac{W}{6}$ cot θ

IX Formulæ for bolt and strap at foot of principal rafter in [illegible] truss—

P = tension on tie-beam = stress on heel [illegible]
For section of each limb of heel strap—

$$S = \frac{P}{f}$$

* $\frac{13}{16}$ cosec 26 35 = 1 81

N B—Round the bolt $\frac{5}{8}$ths of this effective section to be given on each side of the eye

X For diameter of bolt, in inches

$$\text{Diameter} = \frac{\text{Tension on tie beam}}{b \times \frac{1}{4}c}$$

XI In calculating the working resistance of a rivetted joint—

(i) Allow for a shearing stress of 4 tons per square inch for W. I and [illegible] tons for steel

(ii) Allow for a bearing stress of 5 tons per square inch for W. I and 8 tons for steel

Then if n = number of rivets

d = diameter of rivets, in inches

t = thickness of plate, " "

We have for (i) Resistance $= n \times \pi \times \frac{d^2}{4} \times 4$ tons

and for (ii) " $= n \times d \times t \times 5$ "

No rivet hole should be nearer to the edge of the bar than its own diameter or nearer the next than $1\frac{1}{2}$ times its diameter

XII Water supply—

In working out distribution schemes very different results are obtained by employing the different formulæ given in the text books on the subject For "foul" pipes it has been decided to adopt Fanning's formulæ with varying co-efficients which give medium results, and for "slightly tuberculated" either Fanning's or Flammant's formulæ Large pipes, $3\frac{1}{2}$ inch and upwards, will be considered "slightly tuberculated," small pipes "foul"

These formulæ together with Tables XIII and XIV prepared from them are given on pages 117—126 When working with Flammant's formula Baine's slide rule may be used

For further details regarding formulæ for Water supply in pipes, *see* Pamphlet issued by Director General, Military Works, in January, 1898

Loads on Roofs

I *Snow*—5 lbs vertical per s ft for every foot depth of snow likely to accumulate on the roof

II *Work people*—15 lbs vertical per s ft of roof area for roofs up to 20 feet span and 1 lb extra for every additional foot of span up to and including 30 ft span.

No allowance need be made when wind pressure is provided

In calculating roof members for transverse stress, vertical loads must be reduced to normal

III *Wind pressure*—(*a*) This need not be allowed for in roofs of 30 ft span and under, unless the slope is steeper than 1 in 1

(*b*) For spans over 30 and up to 60 feet,—

Roof sloping	$\frac{1}{3}$	allow 18 lbs	normal pressure per sq ft. of roof area.
"	$\frac{1}{2}$	allow 25 lbs	
"	$\frac{2}{5}$	allow 30 lbs.	
"	$\frac{1}{4}$	allow 39 lbs	

(*c*) For all roofs of slope steeper than 1 in 1 and all roofs of greater span than 60 ft full wind pressure to be allowed for, unless there are reasons for special consideration

Full wind pressure may be taken at 60 lbs per s ft on a surface perpendicularly opposed to it, which gives the following normal pressures —

Roofs sloping	$\frac{1}{8}$	—	25 lbs
" "	$\frac{1}{3}$	—	35 lbs
" "	$\frac{2}{4}$	—	12 lbs
" "	$\frac{1}{4}$	—	54 lbs

(*d*) Stresses to be calculated for wind acting on one side only (either with both ends fixed or with one side free to move) in addition to those due to permanent load, *i e*, weight of roof covering and snow if necessary.

Tables.

Table I

Live loads on floors in barracks and officers' messes 112 lbs per square foot dead load

In officers' quarters 90 lbs per square foot dead load

In godowns special calculations of weight must always be made

The weight of steel trusses in lbs per sq ft. of space covered may be taken at 08 × span in feet.

In calculating weights of built up steel girders, add 10 per cent for extra weight at joints, rivet heads, &c

TABLE II

Safe Loads on Foundations

In loamy soil, such as that of the Upper Provinces	80 ton per sq ft
In stiff clays	1 to 1 5 " "
In rock	1 5 to 3 5 " "
On concrete	up to 3 6 " "

TABLE III

Weights of Materials

Brickwork	120 lbs per c ft
Masonry, stone	156 " " "
Concrete, ordinary	115 " " "
" in cement	130 " " "
Plaster	106 " " "
Teak wood or venteak	52 " " "
Vengay	44 " "
Sal	62 " " "
Deodar	40 " "
Chir	32 " "
Sun dried brickwork	100 " "
Clay	130 " " "
Loam	110 " " "
Sand	125 " " "
Corrugated iron roofing, 22 B W G	2 " " sq ft
Naini Tal pattern roofing, 22 B W G, including 1 inch planking	5 " " "
Mangalore tiling	10 " " "
Murree tiling, single, with framing	12 " " "
" " double " "	23 " " "

Goodwyn tiling single	17 lbs per sq ft
" " double	31 " " "
Pan tiles	10 " " "
Mud plaster and reed ceiling	6 " " "
Wrought-iron	28 " " c in
Cast-iron	27 " " "
Steel	288 " " "
Brass	3 " " "
Copper	32 " "
¼" thick steel plate	10 4 lbs per sq ft
Including battens { Double Allahabad tiling,*	34 " " "
Single " †	17 " " "
Country tiling	14 " " "
9" Thatching, including bamboo frames	10 " "
6" Thatching including bamboo frames and matting	6^{1} " " "
4" Terrace roofing on two layers 1½ tiles	100 " "
4½" " on 4½" brick arches	115 " " "
Boarding ¾" thick	2½ " " "
Slating	5 to 11¼ " " "

Weights reduced to normal slope of roof 26° 35 or 1 in 2

Double Allahabad tiling	30 lbs per sq ft
Single " "	15 " " "

Allahabad Tiles

	lbs	oz
* *Double Tiling—*		
1 Flat tile dry	8	12
1 Semi hexagonal tile dry	5	12
1 Flat tile wet	9	14
1 Semi-circular tile wet	4	14
Battens (say)	4	4
	33	8
† *Single Tiling—*		
1 Flat tile wet	[illegible]	14
1 Semi-circular tile wet	4	14
Battens (say)	[illegible]	0
	16	12

TABLE IV

Safe Stress on a ... inch ...

Materials	Tension	Compression	Transverse
	...	...	...
Brickwork Concrete		3 tons per sq. foot	
Teak wood	1300	1250	
Sal "	1210	1210	
Deodar	770	70	
Chir	1200	770	
Deal	1170	700	
Pine red	11250	6960	8750
Wrought iron bolts tie rods &c			4400
Screws nuts &c	3750	20000	8750
Cast iron	*14000	14000	11200
Steel mild	8000		
Copper bolts	22	225	
Gwalior sandstone			

TABLE V

Constants for Timber, &c

Name of Timber &c		Co efficient of Elasticity	Transverse Stress
Botanical	Common	lbs per sq in	lbs per sq in
Tectona grandis	Teak	4 000	650
	Sal	4 125	700

Military Works Handbook, Fourth Edition, page 99, Tabl longifolia", *read* "Pinus excelsa", and *after* "Chir" *add* " c

* For girders tees angles or other sections of mild steel of English manufacture o other manufacture (e g Cossipore) if guaranteed to bear an ultimate stress between 27 an tons per sq in a safe stress of 4½ tons per sq in may be used in cases under a transv stress only

† The Modulus of Elasticity of these timbers is equal to 472 times p or $p = \frac{E}{472}$ app mately

‡ r is the load required to break a bar 1 inch square supported at two points 1 foot and loaded in the middle between the points of support and is equal to $\frac{1}{...}$ of the Modu Rupture or $r = \frac{fp}{18}$ approximately

TABLE VI.

Moments of Inertia, &c

Cross Section	Moment of Inertia I	Moment of Resistance $\mu = \frac{f \times I}{v}$ or $= \frac{c \times I}{d-v}$	Distance of neutral axis from tension edge v
I	$\frac{bd^3}{12}$	$\frac{fbd^2}{6}$	$\frac{d}{2}$
II	$\frac{bd^3-b_1d_1^3}{12}$	$\frac{2 \times c \times I}{d}$	$\frac{d}{2}$
III	$\frac{bd^3-(b_1d_1^3+b_2d_2^3)}{12}$	$\frac{2 \times c \times I}{d}$	$\frac{d}{2}$

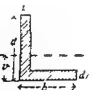
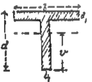
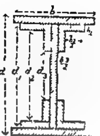
	IX	$\frac{bd^3-(b_1d_1^3+b_2d_2^3+b_3d_3^3)}{12}$	$\frac{2\times c\times I}{d}$	$\frac{d}{2}$
	X	$\frac{1}{3}\{b_2v^3-(b-b_1)(d-d_1-v)^3+b(d-v)^3\}$	$\frac{c\times I}{v}$	$d-\frac{1}{2}\left(\frac{bd_1^2-b_1d_1^2+b_1d^2}{bd_1-b_1d_1+b_1d}\right)$
	XI	$\frac{1}{3}\{bv^3-(b-b_1)(v-d_1)^3+b_1(d-v)^3\}$	$\frac{c\times I}{d-v}$	$\frac{1}{2}\left(\frac{bd_1^2-b_1d_1^2+b_1d^2}{bd_1-b_1d_1+b_1d}\right)$

TABLE VII.

Value of d^3 for { Value of [illegible]

Depth	Breadth 1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$
1	10	12	15	17	20	22	29	27	30	32	35
$1\frac{1}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	44	[illegible]	[illegible]	59	63	[illegible]
$1\frac{1}{2}$	34	42	51	[illegible]	67	76	84	93	101	110	[illegible]
$1\frac{3}{4}$	54	[illegible]	[illegible]	[illegible]	[illegible]	121	[illegible]	147	161	174	[illegible]
2	80	[illegible]	[illegible]	140	[illegible]	[illegible]	200	220	[illegible]	[illegible]	[illegible]
$2\frac{1}{4}$	114	142	171	[illegible]	[illegible]	[illegible]	[illegible]	313	342	370	[illegible]
$2\frac{1}{2}$	[illegible]	[illegible]	234	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$2\frac{3}{4}$	[illegible]	[illegible]	312	[illegible]	416	[illegible]	[illegible]	[illegible]	624	[illegible]	[illegible]
3	270	337	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	810	877	[illegible]
$3\frac{1}{4}$	343	429	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	944	[illegible]	[illegible]	[illegible]
$3\frac{1}{2}$	[illegible]	[illegible]	643	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$3\frac{3}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	119	[illegible]	[illegible]	[illegible]	171	[illegible]
4	640	[illegible]	[illegible]	[illegible]	[illegible]	144	[illegible]	[illegible]	192	[illegible]	[illegible]
$4\frac{1}{4}$	[illegible]	[illegible]	[illegible]	134	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$4\frac{1}{2}$	911	114		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	273	[illegible]	[illegible]
$4\frac{3}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$5\frac{1}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	434	470	[illegible]
$5\frac{1}{2}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	416	[illegible]	[illegible]	[illegible]	[illegible]
$5\frac{3}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	570	[illegible]	[illegible]
6	216	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$6\frac{1}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	610	671	[illegible]	[illegible]	[illegible]
$6\frac{1}{2}$	[illegible]	[illegible]	412	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$6\frac{3}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
7	343	[illegible]	514	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$7\frac{1}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1143	[illegible]	[illegible]
$7\frac{1}{2}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$7\frac{3}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8	512	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$8\frac{1}{4}$	[illegible]	[illegible]	842	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$8\frac{1}{2}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$8\frac{3}{4}$	[illegible]	[illegible]	[illegible]	1172	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9	729	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$9\frac{1}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2176	[illegible]	[illegible]	[illegible]
$9\frac{1}{2}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$9\frac{3}{4}$	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	[illegible]	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$

[illegible]

b varying from 1 to 6.

d " " 1 to 10.

Breadth 3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6
37	40	42	45	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
73	[illegible]	83	88	93	[illegible]	104	107	112	[illegible]
127	135	143	152	160	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
201	214	228	241	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300	320	340	360	350	400	420	440	[illegible]	[illegible]
427	456	494	513	541	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
586	625	664	703	742	781	820	[illegible]	818	[illegible]
780	832	884	936	9?8	104	101	[illegible]	[illegible]	[illegible]
101	103	115	131	128	13	112	[illegible]	[illegible]	[illegible]
129	137	146	154	163	172	180	181	197	[illegible]
161	171	182	193	204	214	22	[illegible]	247	[illegible]
198	211	224	[illegible]	250	[illegible]	[illegible]	280	[illegible]	[illegible]
240	256	27	288	304	320	[illegible]	[illegible]	[illegible]	[illegible]
288	307	3?6	345	[illegible]	384	403	42?	[illegible]	[illegible]
342	364	387	410	433	456	479	[illegible]	[illegible]	[illegible]
402	429	455	482	509	536	[illegible]	[illegible]	[illegible]	[illegible]
469	[illegible]00	531	563	[illegible]	625	[illegible]	[illegible]	71	[illegible]
548	[illegible]	615	651	687	[illegible]21	[illegible]	[illegible]	[illegible]	[illegible]
624	6?5	707	749	[illegible]	842	[illegible]	[illegible]	[illegible]	[illegible]
713	760	8?8	[illegible]	[illegible]	[illegible]	[illegible]	1046	[illegible]	[illegible]
810	864	918	972	102	1080	1134	1188	1242	[illegible]
916	977	1038	1099	1160	1221	[illegible]	1343	1404	[illegible]
1030	1098	1167	12?6	1304	13?3	1442	[illegible]	1579	[illegible]
1153	1230	1307	1384	1461	1538	1615	1692	[illegible]	[illegible]
1286	[illegible]	1458	1543	1629	1715	1801	[illegible]	[illegible]	[illegible]
1429	1524	1620	1715	1810	1905	2001	[illegible]	[illegible]	[illegible]
1582	1687	1793	1898	004	2109	[illegible]	[illegible]	2426	[illegible]
1746	1862	1978	209?	[illegible]11	2327	2444	[illegible]	[illegible]	[illegible]
1920	048	2176	2304	2432	[illegible]	[illegible]	[illegible]816	[illegible]	[illegible]
2106	2246	2386	[illegible]	[illegible]667	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2303	2456	2?10	[illegible]763	2917	3071	3?24	[illegible]	[illegible]	[illegible]
2512	[illegible]	2847	[illegible]	3182	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2734	2916	[illegible]	3283	3463	[illegible]	[illegible]	[illegible]	[illegible]	4374
2968	[illegible]	3?64	3562	[illegible]	[illegible]	4155	[illegible]	[illegible]	[illegible]
3215	3429	[illegible]	[illegible]	4073	[illegible]	4501	[illegible]	[illegible]	5144
3476	3707	[illegible]	4171	4403	4634	[illegible]	[illegible]	[illegible]	[illegible]
3750	4000	4250	4500	4750	5000	[illegible]	[illegible]	[illegible]	[illegible]
3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6

TABLE VIII.

Value of bd^2 for { Value of
"

DEPTH	BREADTH 1	1¼	1½	1¾		2	2¼	2½	2¾		[illegible]	3¼	3½
1	1·0	1·2	1·5	1·7	—	2·0	2·2	2·5	2·7	—	3·0	3·2	3·5
1¼	1·6	2·0	2·3	2·7	—	3·1	3·5	3·9	4·3	—	4·7	5·1	5·5
1½	2·2	2·8	3·4	3·9	—	4·5	5·1	5·6	6·2	—	6·7	7·3	7·9
1¾	3·1	3·8	4·6	5·4	—	6·1	6·9	7·7	8·4	—	9·2	10·0	10·7
2	4·0	5·0	6·0	7·0	—	8·0	9·0	10·0	11·0	—	12·0	13·0	14·0
2¼	5·1	6·3	7·6	8·9	—	10·1	11·4	12·7	13·9	—	15·2	16·2	17·7
2½	6·2	7·8	9·4	10·9	—	12·5	14·1	15·6	17·2	—	18·7	20·4	21·9
2¾	7·6	9·5	11·3	13·2	—	15·1	17·0	18·9	20·8	—	22·7	24·6	26·5
3	9·0	11·2	13·5	15·7	—	18·0	20·2	22·5	24·7	—	27·0	29·2	31·5
3¼	10·6	13·2	15·8	18·5	—	21·1	23·8	26·4	29·0	—	31·7	34·3	37·0
3½	12·2	15·3	18·4	21·4	—	24·5	27·6	30·6	33·7	—	36·7	39·8	42·9
3¾	14·1	17·6	21·1	24·6	—	28·1	31·6	35·2	38·7	—	42·2	45·7	49·2
4	16·0	20·0	24·0	28·0	—	32·0	36·0	40·0	44·0	—	48·0	52·0	56·0
4¼	18·1	22·6	27·1	31·6	—	36·1	40·6	45·2	49·7	—	54·2	58·7	63·2
4½	20·2	25·3	30·4	35·4	—	40·5	45·6	50·6	55·7	—	60·7	65·8	70·9
4¾	22·6	28·2	33·8	39·5	—	45·1	50·8	56·4	62·0	—	67·7	73·3	79·0
5	25·0	31·2	37·5	43·7	—	50·0	56·2	62·5	68·7	—	75·0	81·2	87·5
5¼	27·6	34·5	41·3	48·2	—	55·1	62·0	68·9	75·8	—	82·7	89·6	96·5
5½	30·2	37·8	45·4	52·9	—	60·5	68·1	75·6	83·2	—	90·7	98·3	106
5¾	33·1	41·3	49·6	57·9	—	66·1	74·4	82·7	90·9	—	99·2	107	116
6	36·0	45·0	54·0	63·0	—	72·0	81·0	90·0	99·0	—	108	117	126
6¼	39·1	48·8	58·6	68·4	—	78·1	87·9	97·7	107	—	117	127	137
6½	42·2	52·8	63·4	73·9	—	84·5	95·1	106	116	—	127	137	148
6¾	45·6	57·0	68·3	79·7	—	91·1	103	114	125	—	137	148	159
7	49·0	61·2	73·5	85·7	—	98·0	110	122	135	—	147	159	171
7¼	52·6	65·7	78·9	92·0	—	105	118	131	145	—	158	171	184
7½	56·2	70·3	84·4	98·4	—	112	127	141	155	—	169	183	197
7¾	60·1	75·1	90·1	105	—	120	135	150	165	—	180	195	210
8	64·0	80·0	96·0	112	—	128	144	160	176	—	192	208	224
8¼	68·1	85·1	102	119	—	136	153	170	187	—	204	221	238
8½	72·2	90·3	108	126	—	144	163	181	199	—	217	235	253
8¾	76·6	95·7	115	134	—	153	172	191	211	—	230	249	268
9	81·0	101	121	142	—	162	182	202	223	—	243	263	283
9¼	85·6	107	128	150	—	171	192	214	235	—	257	278	299
9½	90·2	113	135	158	—	180	203	226	248	—	271	293	316
9¾	95·1	119	143	166	—	190	214	238	261	—	285	309	333
1	100	125	150	175	—	200	225	250	275	—	300	325	350
	1	1¼	1½	1¾		2	2¼	2½	2¾		3	3¼	3½

b varying from 1 to 6.

d „ „ 1 to 10.

Breadth 3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	Depth
3·7	4·0	4·2	4·5	4·7	5·0	5·2	5·5	5·7	6·0	1
5·9	6·2	6·6	7·0	7·4	7·8	8·2	8·6	9·0	9·4	1¼
8·4	9·0	9·6	10·1	10·7	11·2	11·8	12·4	12·9	13·5	1½
11·5	12·3	13·0	13·8	14·6	15·3	16·1	16·8	17·6	18·4	1¾
15·0	16·0	17·0	18·0	19·0	20·0	21·0	22·0	23·0	24·0	2
19·0	20·2	21·5	22·8	24·0	25·3	26·6	27·8	29·1	30·4	2¼
23·4	25·0	26·6	28·1	29·7	31·2	32·8	34·4	35·9	37·5	2½
28·4	30·2	32·1	34·0	35·9	37·8	39·7	41·6	43·5	45·4	2¾
33·7	36·0	38·2	40·5	42·7	45·0	47·2	49·5	51·7	54·0	3
39·6	42·2	44·9	47·5	50·2	52·8	55·5	58·1	60·7	63·4	3¼
45·9	49·0	52·1	55·1	58·2	61·2	64·3	67·4	70·4	73·5	3½
52·7	56·2	59·8	63·3	66·8	70·3	73·8	77·3	80·9	84·4	3¾
60·0	64·0	68·0	72·0	76·0	80·0	84·0	88·0	92·0	96·0	4
67·0	72·2	76·8	81·3	85·8	90·3	94·8	99·3	104	108	4¼
75·9	81·0	86·1	91·1	96·2	101	106	111	116	121	4½
84·6	90·2	95·9	102	107	113	118	124	130	135	4¾
93·7	100	106	112	119	125	131	137	144	150	5
103	110	117	124	131	138	145	152	158	165	5¼
113	121	129	136	144	151	159	166	174	181	5½
124	132	141	149	157	165	174	182	190	198	5¾
135	144	153	162	171	180	189	198	207	216	6
146	156	166	176	186	195	205	215	225	234	6¼
158	169	180	190	201	211	222	232	243	253	6½
171	182	194	205	216	228	239	251	262	273	6¾
184	196	208	220	233	245	257	269	282	294	7
197	210	223	237	250	263	276	289	302	315	7¼
211	225	239	253	267	281	295	309	323	337	7½
225	240	255	270	285	300	315	330	345	360	7¾
240	256	272	288	304	320	336	352	368	384	8
255	272	289	306	323	340	357	374	391	408	8¼
271	289	307	325	343	361	379	397	415	433	8½
287	306	325	345	364	383	402	421	440	459	8¾
304	324	344	364	384	405	425	445	465	486	9
321	342	364	385	406	428	449	470	492	513	9¼
338	361	384	406	429	451	474	496	519	541	9½
356	380	404	428	452	475	499	523	547	570	9¾
375	400	425	450	475	500	525	550	575	600	10
3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	

TABLE IX.

TABLE OF STRENGTH OF ⊤ STEEL BEAMS

British Standard Sections

L = Span in feet   Beams supported at both ends

I = Moment of Inertia

v = Distance of neutral axis from the extreme edge of Tension flange.

K, K_1 = Constants for each section

W = Total safe load in tons distributed over span including weight of steel beams with limiting stress of 7 5 tons per sq in in tension and 6½ tons in compression

To use the Table the rules on pages 113 and 114 are to be followed

Dimensions of Section in Inches			Weight per foot	Sectional Area	Values of			Constants		
Breadth b	Depth d	Thickness	Lbs	Sq In	Least Radius of Gyration	I	v or $d-v$	K For Load $W < \frac{K}{L}$	K For Load $W < \frac{K}{L}$	K_1 For deflection $\frac{WL^3}{I D} < K_1$
1	1	125	82	240	191	021	711	148	123	0020
		187	1 17	344						
1¼	1¼	125	1 03	303	237	042	902	241	101	0058
		187	1 49	[illegible]						
1½	1½	187	1 81	531	301	100	1 065	198	114	0147
		250	2 35	6[illegible]2						
1¾	1¾	187	2 14	[illegible]	3[illegible]0	173	1 258	[illegible]9	573	·0210
		250	2 79	820						
1½	2	250	2 79	820	2·8	307	1 3[illegible]2	1 14	·946	·0126
		312	3 40	1·001						
[illegible]	2	250	3 22	947	407	[illegible]37	1 421	1 19	·998	·0403
		312	3 94	1 159						
		375	4 61	1 376						
2¼	2¼	250	3 64	1 071	457	498	1 612	1 51	1 20	·0[illegible]8
		312	4 47	1 314						
		375	5 29	1 5[illegible]3						
2½	2½	250	4 07	1 197	[illegible]02	[illegible]	1 [illegible]	1 [illegible]8	1 66	·0[illegible]10
		312	5 00	1 471						
		375	5 [illegible]2	1 741						
3	[illegible]	312	5 01	1 472	[illegible]07	4[illegible]7	1 491	1 53	1 27	·0631
		375	[illegible]43	1 [illegible]43						
3	[illegible]	312	5 53	1 627	610	[illegible]	1 8[illegible]0	2·37	1 97	1207
		375	6 56	1 [illegible]						
[illegible]	3	312	6 0[illegible]	1 7[illegible]	612	1·4[illegible]6	2 15[illegible]	3 37	2 81	2022
		375	7 21	2 121						
		437	8 30	2 441						
3	4	375	8 48	2 491	571	3 822	2 7[illegible]	6 93	5 77	5·08
		500	11 07	3 [illegible]56						

TABLE IX—(*continued*)

Dimensions of Section in Inches			Weight per Foot	Sectional Area	Values of			Constants (T section, b, d)	Constants (inverted T section, b, d−t)	Constants
Breadth b	Depth d	Thickness	Lbs	Sq in	Least Radius of Gyration	I	v or d−t	k For Load $W<\frac{k}{L}$	K For Load $W<\frac{K}{L}$	K_1 For deflection $\frac{WL^2}{100}<K_1$
3½	3½	375	8 49	2 496	717	2 768	2 512	5 51	4 59	3844
		437	9 78	2 878						
		500	11 08	3 258						
4	3	375	8 49	2 498	863	1 860	2 233	4 16	3 47	2583
		500	11 08	3 260						
4	4	375	9 77	2 872	814	4 189	2 894	7 21	6 03	5818
		500	12 78	3 758						
4	5	37[illegible]	11 06	3 253	762	7 771	3 531	11 00	9 16	1 0793
		500	14 50	4 264						
5	3	375	9 78	2 875	828	1 373	2 309	4 27	3 56	2740
		500	12 [illegible]0	3 762						
5	3½	500	13 66	4 018	990	3 936	2 608	7 65	6 28	5466
5	4	500	14 51	4 268	1 084	5 772	2 04[illegible]	9 79	8 15	8017
6	3	375	11 08	3 260	795	2 062	2 367	4 35	3 62	2804
		500	14 53	4 272						
6	4	500	16 22	4 771	1 128	6 070	3 03[illegible]	10 [illegible]0	8 34	8430
7	3½	500	17 08	5 023	924	4 28[illegible]	2 736	7 83	6 52	59[illegible]1

(1) Approximate moments of inertia for other thicknesses can be obtained from the given values by multiplying them by the ratio of the weights (or sectional areas)

Radius of gyration $= \sqrt{\frac{I}{a}}$ where I = moment of inertia and a = sectional area

TABLE X

Table of Strength of ∟ Steel Beams

British Standard Sections

Same data as for T steel page 106

Dimensions of Section in Inches			Weight per Foot	Sectional Area	Values of			Constants		
Breadth b	Depth d	Thickness	Lbs	Sq in	Least Radius of Gyration	I	y or d−y	K For Load $W<\frac{K}{L}$	K For Load $W<\frac{K}{L}$	K_1 F = deflection $\frac{WL^3}{100}<K_1F$
1	1	125	80	234	185	020	715	130	110	0028
		250	1 49	437						
1	1¼	125	90	265	204	038	860	218	181	[illegible]
		250	1 70	500						
1¼	1¼	125	1 02	299	238	041	904	[illegible]	[illegible]	[illegible]
		250	1 92	564						
1½	1½	125	1 11	[illegible]	[illegible]	068	1 0[illegible]	[illegible]	[illegible]	[illegible]
		250	2 12	621						
1½	1½	125	1 23	361	[illegible]	[illegible]	1 091	[illegible]	292	[illegible]
		250	[illegible]	689						
1¾	1¾	175	1 83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		300	3 01	[illegible]						
1¾	1¾	175	[illegible]	583	[illegible]	162	[illegible]	612	[illegible]	[illegible]
		300	[illegible]	[illegible]						
1¾	[illegible]	175	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]8	[illegible]	[illegible]	0012
		300	[illegible]27	·961						
2	[illegible]	175	[illegible]	[illegible]	358	244	1 461	840	700	[illegible]
		300	3 77	1 110						
[illegible]	[illegible]	[illegible]	[illegible]57	[illegible]	[illegible]	460	1 7[illegible]	[illegible]	1 0[illegible]	[illegible]
		300	[illegible]28	1 200						
2¼	2¼	175	[illegible]	[illegible]	[illegible]	[illegible]	1 639	1 08	[illegible]	·0191
		300	4 23	1 200						
2½	2½	250	[illegible]	1 18[illegible]	[illegible]	677	1 [illegible]9	[illegible]	1 [illegible]6	[illegible]
		375	[illegible]	1 [illegible]						
		500	7 6[illegible]	2 219						
2¾	[illegible]	250	4 46	1 312	[illegible]	917	1 9[illegible]	2 [illegible]0	1·91	127
		375	[illegible]	1·921						
		500	8 [illegible]0	2 4[illegible]						
[illegible]	[illegible]	250	4 04	1 187	[illegible]	1·0[illegible]	20[illegible]	2 0[illegible]	[illegible]16	[illegible]
		375	[illegible]	1 [illegible]						
		500	7 6[illegible]	[illegible]						
2[illegible]	[illegible]	[illegible]	4 46	1 312	[illegible]21	1 1[illegible]	2 10[illegible]	2 [illegible]0	[illegible]	1[illegible]
		375	[illegible]	1 921						
		500	[illegible]	[illegible]						
3	3	250	4 [illegible]	1 440	[illegible]	1 207	2 173	[illegible]	[illegible]	[illegible]
		375	7 19	2 111						
		500	9 3[illegible]	2 75[illegible]						

TABLE X—(*continued*)

Dimensions of Section in Inches			Weight per Foot	Sectional Area	Values of			Constants		
Breadth b	Depth d	Thick t	W	Sq in	Least Radius of Gyration	I	I/c or d	K For Load $W = \frac{K}{L}$	K For Load $W = \frac{K}{L}$	K_1 For deflection $\frac{WL^2}{100} = K_1$
2½	3½	250	4 90	1 440	537	1 758	2 405	[illegible]	[illegible]	244
		375	7 18	2 112						
		500	9 36	2 752						
3	3½	250	5 31	1 563	624	1 853	2 486	3 72	3 10	[illegible]
		375	7 81	2 298						
		500	10 20	3 001						
3½	3½	300	6 84	2 011	684	[illegible]	[illegible]	[illegible]	[illegible]	319
		425	9 50	2 795						
		500	11 05	3 251						
2½	4	250	5 31	1 563	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		375	7 81	2 298						
		500	10 20	3 001						
3	4	300	6 84	2 011	641	[illegible]	[illegible]	[illegible]	4 80	44
		425	9 50	2 795						
		500	11 05	3 251						
3½	4	300	7 34	2 159	723	3 334	2 843	[illegible]	[illegible]	[illegible]
		425	10 22	3 006						
		500	11 90	3 499						
4	4	300	7 85	2 310	785	[illegible]	2 309	[illegible]	[illegible]	[illegible]
		425	10 94	3 219						
		500	12 75	3 749						
3	4½	300	7 34	2 159	[illegible]	[illegible]	3 062	[illegible]	5 99	[illegible]
		425	10 22	3 006						
		500	11 90	3 499						
3½	4½	300	7 85	2 309	[illegible]	[illegible]	[illegible]		[illegible]	641
		425	10 94	3 219						
		500	12 75	3 749						
3	5	300	7 85	2 309	649	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		425	10 94	3 219						
		500	12 75	3 749						
3½	4½	375	11 00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		500	14 46	4 252						
3½	5	375	10 37	3 050	[illegible]	[illegible]	3 410	11 20	9 33	1 002
		500	13 61	4 003						
4	5	375	11 00	3 236	[illegible]	[illegible]	[illegible]	11 39	9 49	1 106
		500	14 46	4 252						
5	5	375	12 27	3 610	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		500	16 15	4 750						
3	5½	375	10 37	3 050	644	9 118	[illegible]	13 11	10 92	1 312
		500	13 61	4 003						
3½	5½	375	11 00	3 236	[illegible]	[illegible]	[illegible]	13 41	[illegible]	[illegible]
		500	14 46	4 252						

TABLE X

Table of Strength of ⌊ Steel Beams

British Standard Sections

Same data as for ⊤ steel page 106

Dimensions of Section in Inches			Weight per Foot	Sectional Area	Values of			Constants		
Breadth b	Depth d	Thickness	Lbs	Sq in	Least Radius of Gyr r	I	y or $d-y$	K For Load $W < \frac{K}{L}$	K For Load $W < \frac{K}{L}$	k_1 For deflection $\frac{WL^3}{100} < k_1$
1	1	125	80	231	185	020	715	130	116	00[illegible]8
		250	1 49	437						
1	1¼	125	90	265	204	038	869	218	181	00[illegible]
		250	1 70	500						
1¼	1¼	125	1 09	299	[illegible]38	041	901	2[illegible]6	1[illegible]8	00[illegible]7
		250	1 97	564						
1½	1½	125	1 11	32[illegible]	[illegible]	064	1 062	[illegible]	[illegible]	·0004
		250	2 12	[illegible]						
1½	1½	125	1 23	361	293	[illegible]	1 091	[illegible]	2[illegible]2	010[illegible]
		250	[illegible]31	[illegible]						
1½	1¾	175	1 83	540	[illegible]	[illegible]	1[illegible]8	627	22	·0[illegible]11
		300	3 01	8[illegible]6						
1¾	1¾	175	1 99	[illegible]83	[illegible]	16[illegible]	1[illegible]	[illegible]42	[illegible]	[illegible]
		300	3[illegible]7	[illegible]						
1½	2	175	1 98	583	[illegible]	[illegible]	1 378	816	[illegible]	[illegible]12
		300	3 2[illegible]	·961						
2	2	175	2 28	670	388	214	1 401	810	700	[illegible]
		300	3 77	1 110						
[illegible]	[illegible]	175	2 57	757	[illegible]	400	17[illegible]	1 [illegible]	1 0[illegible]	[illegible]
		300	4 23	1 200						
2½	2½	175	[illegible]57	[illegible]	139	[illegible]	1 639	108	[illegible]	·0101
		300	4 23	1 200						
2½	2½	2[illegible]0	4 04	1 18[illegible]	4[illegible]	677	1 79[illegible]	1 [illegible]	1 [illegible]6	[illegible]01
		[illegible]	60	1 [illegible]						
		[illegible]	7 6[illegible]	[illegible]219						
2½	[illegible]	2[illegible]	4 4[illegible]	1 312	[illegible]	917	1 98[illegible]	2 [illegible]	1·01	12[illegible]
		3[illegible]	[illegible]	1 921						
		[illegible]0	8 [illegible]0	[illegible]499						
2	3	2[illegible]0	4 04	1 187	4[illegible]7	10[illegible]	20[illegible]	2[illegible]	2 16	11[illegible]
		3[illegible]	[illegible]	1 743						
		[illegible]	7 6	[illegible]19						
2½	3	[illegible]	4 4[illegible]	1 312	[illegible]	1 1[illegible]	2 1[illegible]	2[illegible]0	2 2[illegible]	1 [illegible]
		37[illegible]	[illegible]	1 921						
		[illegible]	8 [illegible]	[illegible]						
[redacted]	[redacted]	2[illegible]	4 [illegible]	1 440	[illegible]	1 20[illegible]	2 173	2[illegible]	2 [illegible]	10[illegible]
		3[illegible]	7 19	2 111						
		[illegible]	[illegible]	2 [illegible]52						

TABLE X—(*continued*)

Dimensions of Section in Inches			Weight per Foot	Sectional Area	Values of			Constants	
Breadth b	Depth d	Thickness	Lb	Sq in	Least Radius of Gyration	I	$\frac{I}{c}$	K For Load W = $\frac{K}{L}$	K For Load W = $\frac{K}{L}$
2½	3½	250	4 90	1 440	537	1 758	2 405	[illegible]	3 04
		375	7 18	2 112					
		500	9 36	2 752					
3	3½	250	5 31	1 563	624	1 853	2 49[illegible]	[illegible]	5 10
		375	7 81	2 298					
		500	10 20	3 001					
3½	3½	300	6 84	2 011	[illegible]	2 299	2 531	[illegible]	[illegible]78
		425	9 50	2 795					
		500	11 05	3 251					
2½	4	250	5 31	1 563	540	[illegible]	[illegible]	4 69	[illegible]99
		375	7 81	2 298					
		500	10 20	3 001					
3	4	300	6 84	2 011	641	[illegible]	2 7[illegible]	[illegible]	4 80
		425	9 50	2 795					
		500	11 05	3 251					
3½	4	300	7 34	2 159	723	3 334	2 845	[illegible]	4 88
		425	10 22	3 006					
		500	11 90	3 499					
4	4	300	7 85	2 310	785	[illegible]	2 909	[illegible]	4 97
		425	10 94	3 219					
		500	12 75	3 749					
3	4½	300	7 34	2 159	647	4 40[illegible]	3 062	[illegible]	5 99
		425	10 22	3 006					
		500	11 90	3 499					
3½	4½	300	7 85	2 309	[illegible]	4 641	3 14		[illegible]
		425	10 94	3 219					
		500	12 75	3 749					
3	5	300	7 85	2 309	649	[illegible]	[illegible]	[illegible]	7 35
		425	10 94	3 219					
		500	12 75	3 749					
4½	4½	375	11 00	3 236	[illegible]82	6 141	3 2[illegible]	[illegible]4	[illegible]
		500	14 46	4 252					
3½	5	375	10 37	3 050	[illegible]	[illegible]44	[illegible]410	11 [illegible]0	9[illegible]
		500	13 61	4 003					
4	5	375	11 00	3 236	[illegible]	[illegible]	[illegible]	11 39	
		500	14 46	4 252					
5	5	375	12 27	3 610	[illegible]	[illegible]	[illegible]	11 70	9 [illegible]
		500	16 15	4 750					
3	5½	375	10 37	3 050	644	9 448	[illegible]001	13 11	10 92
		500	13 61	4 003					
3½	5½	375	11 00	3 236	[illegible]	9 93[illegible]	3 [illegible]63	13 41	
		500	14 46	4 252					

TABLE X—(*concluded*)

Dimensions of Section in Inches.			Weight per Foot	Sectional Area	Values of			Constants		
Breadth b	Depth d	Thickness	Lbs	Sq in	Least radius of Gyration	I	y or d−y	k For Load $W=\frac{k}{L}$	K For Load $W=\frac{k}{L}$	k_1 For deflection $\frac{WL^3}{D}=k_1$
3½	6	.375	11.64	3.424	.757	12.646	3.989	15.85	13.20	1.756
		.500	15.31	4.502						
4	6	.375	12.27	3.610	.867	13.191	4.083	16.13	13.44	1.832
		.500	16.15	[illegible]						
3½	6½	.375	[illegible]	3.610	.753	15.728	[illegible]	18.30	15.32	2.184
		.500	16.15	[illegible]						
6	6	[illegible]	[illegible]	[illegible]	1.180	[illegible]	4.357	[illegible]	[illegible]	[illegible]
		[illegible]	24.18	7.112						
4	6½	[illegible]	17.81	[illegible]	.862	[illegible]	4.312	[illegible]	21.00	[illegible]
[illegible]	6½	[illegible]	[illegible]	[illegible]	[illegible]	21.213	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	21.33	3.641
7	7	.500	[illegible]	[illegible]	[illegible]	31.415	[illegible]	30.87	[illegible]	[illegible]
		[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		[illegible]	[illegible]	11.43						
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	43.01	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	819	[illegible]	[illegible]	74.31	[illegible]	[illegible]

NOTE—( ) Approximate moments of inertia for other thicknesses can be obtained from the given values by multiplying them by the ratio of the weights (or sectional area.)

( ) Radius of gyration $=\sqrt{\frac{I}{a}}$ when I = moment of inertia and a = sectional area.

TABLE XI

TABLE OF STRENGTH OF ROLLED STEEL BEAMS

The Tables and Constants are arranged to give a limiting stress of $7\frac{1}{2}$ tons per square inch for mild steel, but it is to be distinctly understood that this stress is to be used only in the case of girders obtained on indent from England, or of girders purchased locally, which are guaranteed to bear an ultimate stress of from 27 to 32 tons per square inch

The constants for load and deflection of girders not in the Table can readily be obtained from their moments of inertia, by the following formulæ —

CASE I —For distributed loads, ends of joist supported

(a) *For loads*—

$$\frac{Wl}{8} = \frac{2SI}{d}$$

$$WL = \frac{2SI}{d} \times \frac{8}{12}$$

$$= \frac{\frac{4}{3} \times 7\frac{1}{2} \times I}{d} = \frac{10\,I}{d} = K \text{ constant for load}$$

(b) *For deflection*—

$$V = \frac{5}{384}\,\frac{Wl^3}{E \times I}$$

$$= \frac{5 \times (12\,L)^3\,W}{384 \times 12500 \times I} = \frac{9}{5000} \times \frac{WL^3}{I}$$

Taking the maximum deflection permissible to be $\frac{1}{40}$ inch per foot run of span,

$$V = \frac{L}{40} = \frac{9}{5000} \times \frac{WL^3}{I}$$

Whence $\frac{WL^2}{100} = \frac{5}{36} \times I = K_1$ constant for deflection

where —

W = Total distributed load *(in tons)* including weight of joist
L = Clear span *(in feet)*
l = " " *(in inches)*

S = Limiting stress *(in tons)* per square inch ($7\frac{1}{2}$ for mild steel)
E = Modulus of elasticity *(in tons)* per square inch (12,500 for mild steel)

I = Moment of inertia of section of joist (*in quartic inches*)

Δ = Deflection (*in inches*) at centre of span

d = Depth of joist (*in inches*)

Table of Rolled Steel Joists

British Standard Sections

With particulars of Sections and Constants for Load and Deflection, with a Limiting Stress of 7·5 tons per square inch

Case I { Condition of joist — Supported at both ends
Arrangement of load — Dead, uniformly distributed, weight of joist included

Section in Inches	Weight in lbs per lineal foot	Thickness of web in Inches	Moment of Inertia in quartic inches	Constants: k For Load $W < \frac{K}{L}$	Constants: k_1 For Deflection $\frac{WL^3}{I\Delta} < k_1$	Sectional Area in Inches	Least Radius of Gyration
21×7½	100	[illegible]	2054·760	1100·1[illegible]3	368·718	29·39	1·508
20×7½	89	[illegible]	1671·[illegible]91	8[illegible]5·615	242·123	26·10	1·517
18×7	7[illegible]	[illegible]5	1149·667	[illegible]·701	1[illegible]9·0[illegible]6	22·07	1·453
16×6	[illegible]	[illegible]	72[illegible]·[illegible]	451·720	100·856	18·23	1·219
15×6	[illegible]	[illegible]	629·0[illegible]	419·[illegible]96	87·174	17·35	1·275
15×[illegible]	42	[illegible]	428·207	[illegible]·471	[illegible]·471	12·3[illegible]	·983
14×[illegible]	[illegible]	[illegible]	[illegible]	[illegible]·770	71·010	1[illegible]·77	1·[illegible]
14×[illegible]	46	[illegible]	110[illegible]	[illegible]·742	[illegible]·197	1[illegible]	1·[illegible]
12×[illegible]	54	[illegible]	[illegible]	112·000	[illegible]·166	[illegible]	1·[illegible]
12×[illegible]	44	[illegible]	315·4[illegible]	262·[illegible]	47·511	12·[illegible]	1·111
12×5	[illegible]		2[illegible]·115	1[illegible]·429	[illegible]·571	9·10	1·018
1[illegible]×8	70	[illegible]	[illegible]	[illegible]	47·[illegible]22	[illegible]	1·[illegible]
10×[illegible]	42	[illegible]	211·611	211·611	[illegible]	12·[illegible]	1·[illegible]
10×[illegible]	[illegible]	[illegible]	145·6[illegible]	[illegible]	[illegible]	8·82	1·033
9×7	58	[illegible]	229·740	[illegible]	[illegible]	17·06	1·6[illegible]7
9×4	21	[illegible]	81·115	[illegible]·127	11·[illegible]	[illegible]·17	·[illegible]
8×[illegible]	[illegible]	44	110·[illegible]	13[illegible]·216	1[illegible]·[illegible]	10·29	1·[illegible]
8×5	[illegible]		[illegible]	111·[illegible]	12·410	8·[illegible]	1·11[illegible]
8×4	18	[illegible]	[illegible]	[illegible]	7·735	[illegible]	·[illegible]
7×4	16	[illegible]	[illegible]	[illegible]·031	[illegible]·117	4·70	·[illegible]
[illegible]×[illegible]	[illegible]	41	43·611	72·[illegible]	[illegible]	[illegible]	1·111
[illegible]×4½	[illegible]		34·[illegible]	[illegible]·702	4·[illegible]	[illegible]	·[illegible]
[illegible]	12		[illegible]	[illegible]·713	4·[illegible]	[illegible]	·[illegible]
[illegible]×4½	1[illegible]	[illegible]	22·[illegible]	45·[illegible]	[illegible]	[illegible]	1·0[illegible]
[illegible]	11	[illegible]	1[illegible]	2[illegible]·[illegible]	1·[illegible]	[illegible]	·[illegible]
4½×1¾	[illegible]	1[illegible]	6·[illegible]7	14·2[illegible]	·[illegible]	1·[illegible]	·[illegible]
4×3	[illegible]	[illegible]	7·5[illegible]	[illegible]	1·045	[illegible]	·[illegible]
4×1¾	[illegible]	17	3·671	9·177	[illegible]	1·47	·[illegible]
[illegible]×3	[illegible]	[illegible]	3·7[illegible]	12·630	[illegible]	[illegible]	·710
3×1½	4	16	1·[illegible]	5·523	[illegible]	1·17	·[illegible]

To use the foregoing Table—

(i) To select a joist for a given external load (*i e*, load exclusive of weight of joist) and a given span —

Multiply the load *(in tons)* by the clear span *(in feet)* and select a section from the Table, against which the constant for load "K" is slightly higher than the result

The weight of the joist should then be added to the external load and the section selected tried, as shown in *(ii)* and *(iii)* below, for load and deflection

(ii) To find the load for a given section of joist with a given span —

Divide the constant for load "K" by the span *(in feet)*

The quotient is the safe distributed load *(in tons)*, including the weight of the joist *

For Load—

$$\frac{K}{L} \times c \text{ must be} \left\{ \begin{array}{c} \text{equal to} \\ \text{or} \\ \text{greater than} \end{array} \right\} W \text{ tons}$$

(iii) To determine whether for a given section of joist and a given span, the resultant deflection caused by a given load, including weight of girder will be greater than the maximum deflection permissible, *i e*, $\frac{1}{40}$ inch per foot run of span

Multiply the total weight *(in tons)* by the square of the span *(in feet)* and divide by 100

If the quotient is equal to or less than the constant for deflection, it will show that the maximum deflection permissible has not been exceeded

Note—c and c_1 in (ii) and (iii) are the constants for load and deflection due to different conditions of the girders and will be found on the following page for Cases II to VIII

FOR DEFLECTION—

$$\frac{W\ tons \times L^3}{100} \times c_1 \text{ must be} \left\{ \begin{array}{c} \text{equal to} \\ \text{or} \\ \text{less than} \end{array} \right\} K_1$$

N.B.—In cases where it is considered that a deflection of $\frac{1}{40}$ inch per foot (run is excessive, as for instance in very long spans, or for other reasons), the following formula for deflection must be used:—

FOR DEFLECTION—

$$\frac{W\ tons \times L^3}{4000 \times D_1} \times c_1 \text{ must be} \left\{ \begin{array}{c} \text{equal to} \\ \text{or} \\ \text{less than} \end{array} \right\} K_1$$

where D_1 is the maximum deflection *(in inches)* considered advisable.

CASES II TO VIII

To ascertain loads, etc., in the following cases, the results in (*ii*) and (*iii*) above have to be multiplied by the constants "*c*" and "c_1" respectively, given below.

Case	Condition of joist	Arrangement of load (dead in all cases)	Factors to be applied to	
			Load constant *c*	Deflection constant c_1
II	Fixed at both ends	Uniformly distributed	1·5	·2
III	Fixed at one end, supported at the other	" " "	1	·415
IV.	Fixed at one end, free at the other	" "	·25	9·6
V	Supported at both ends	Concentrated at centre	·5	1·6
VI	Fixed at both ends	" "	1	·4
VII.	Fixed at one end, supported at the other	" "	¾	·711
VIII	Fixed at one end, free at the other	Concentrated at free end	·125	25·6

In cases V and VIII, total load = external load + ½ weight of joist.
VI and VII, total load = external load + ⅝ weight of joist.

TABLE XII

Table showing Strength of Columns of Cast Iron, Wrought Iron and Steel (Fuller's Formula).

l = length of strut between ends in inches.

k = least radius of gyration, *vide* Tables IX, X and XI.

r_c = one-fourth of the approximate breaking weight of struts in tons per square inch.

TABLE XII

$\frac{l}{k}$	f_c					
	Cast Iron		*Wrought Iron*		*Steel*	
	Ends rounded	Ends fixed	Ends rounded.	Ends fixed	Ends rounded	Ends fixed
10	8.63	8.83	4.00	4.00	5.33	5.34
15	8.41	8.76	3.98	4.00	5.26	5.31
20	8.07	8.65	3.92	3.99	5.20	5.29
25	7.58	8.46	3.88	3.98	5.13	5.24
30	6.98	8.21	3.80	3.95	5.02	5.20
35	6.32	7.91	3.72	3.93	4.90	5.15
40	5.68	7.56	3.64	3.89	4.76	5.09
45	5.02	7.19	3.54	3.86	4.58	5.03
50	4.43	6.82	3.44	3.82	4.40	4.98
55	3.84	6.46	3.31	3.78	4.22	4.92
60	3.35	6.10	3.17	3.73	4.02	4.83
65	2.97	5.75	3.04	3.68	3.80	4.75
70	2.57	5.39	2.90	3.63	3.59	4.67
75	2.23	5.02	2.76	3.55	3.37	4.56
80	1.96	4.68	2.60	3.48	3.15	4.45
85	1.74	4.33	2.46	3.40	2.96	4.35
90	1.50	4.00	2.33	3.32	2.77	4.25
95	1.42	3.66	2.18	3.22	2.56	4.13
100	1.29	3.35	2.03	3.17	2.40	4.00
105	1.17	3.07	1.92	3.08	2.24	3.88
110	1.07	2.80	1.79	3.00	2.09	3.74
115	0.99	2.57	1.67	2.91	1.95	3.61
120	0.93	2.37	1.57	2.82	1.83	3.46
125	0.86	2.19	1.47	2.74	1.71	3.32
130	0.80	2.03	1.39	2.66	1.61	3.21
135	0.75	1.90	1.32	2.58	1.50	3.09
140	0.70	1.78	1.24	2.48	1.42	2.96
145	0.66	1.66	1.17	2.40	1.36	2.85
150	0.61	1.53	1.10	2.32	1.28	2.72
160	0.56	1.40	0.99	2.14	1.13	2.51
170	0.49	1.25	0.88	2.00	1.01	2.32
180	0.43	1.14	0.80	1.84	0.91	2.13
190	0.39	1.03	0.72	1.70	0.83	1.97
200	0.36	0.93	0.66	1.57	0.75	1.83
210	0.32	0.84	0.58	1.46	0.68	1.68
220	0.30	0.77	0.55	1.35	0.62	1.55
230	0.28	0.70	0.50	1.26	0.58	1.44
240	0.25	0.64	0.46	1.18	0.53	1.34
250	0.23	0.59	0.42	1.11	0.49	1.25
260	0.22	0.56	0.40	1.04	0.46	1.16
270	0.20	0.52	0.37	0.97	0.42	1.08
280	0.19	0.49	0.35	0.91	0.39	1.01
290	0.18	0.46	0.33	0.86	0.37	0.96
300	0.17	0.43	0.30	0.80	0.35	0.92

For Sections given below $\frac{l}{k} = n\frac{l}{b}$

Section	Value of n
	3.0
Hollow; Metal thin	3.1
	3.8
	4.3
	3.5

Areas and radii of gyration of B. S. beams tees and angles are given on pages 106 to 110 and 112.

The unsupported length of a strut should not be greater than 50 times the least dimension or 150 times the value of k

In calculating steel trusses which are geometrically similar to those described in Examples V and VI the following constants may be made use of —

I —Truss simi	Compression	A 1,	2 24 W
lar to that describ	„	A 2,	2 02 W
ed in Example V,	„	A 3,	45 W
page 141, (*Plate*	Tension	C 1,	2 03 W
II)	„	C 2,	88 W
	„	C 3,	1 21 W
II —Truss simi	Compression	A 1,	2 48 W + 1 42 W_1
lar to that describ	„	A 2,	2 35 W + 1 42 W_1
ed in Example VI,	„	A 3,	1 76 W + 97 W_1
page 147, (*Plate*	„	A 4,	31 W + 33 W_1
III)	„	A 5,	46 W + 5 W_1
	Tension	C 1,	2 0 W + 1 52 W_1
	„	C 2,	1 8 W + 1 0 W_1
		C 3,	1 25 W + 51 W_1
	„	C 4	45 W + 5 W^1
	„	C 5,	7 W + 64 W_1

In all cases W equals the weight of the permanent load, and W_1 the wind pressure on half the truss, and may be taken either in lbs or tons For trusses worked out similar to that described in Example VII, page 155 constants are not applicable

TABLE XIII

Foul Pipes.

Head of water consumed by friction in pipes 100 feet long calculated by Fanning's formula with varying co-efficients for foul pipes

$$H = \frac{G^2 \times m \times L}{5·3767 \times d^5}$$

Gallons per minute	Diameter of pipe in inches				
	1	1½	2	2½	3
	Value of m				
	015	0145	·014	0135	013
	Head of water in feet				
1	26898	03424	00785	00248	00096
2	1 07590	13696	03138	00992	00384
3	2 42079	30816	07061	02231	00863
4	4 30362	54784	12552	03966	01535
5	6 72441	85600	19613	06197	02398
6	9 68314	1 23263	28242	08924	·03454
7	13 17983	1 67775	38441	12147	·04701
8	17 21448	2 19135	50209	15865	06140
9	21 78707	2 77342	63545	20079	07771
10	26 89762	3 42398	78451	24789	09594
11	32 54612	4 14302	94926	29995	11608
12	38 73257	4 93053	1 12969	35696	13815
13	45 45698	5 78653	1 32582	41893	16213
14	52 71934	6 71100	1 53764	48586	18803
15	60 51965	7 70396	1 76516	55775	21585
16	68 85791	[illegible] 76539	2 00835	63460	24559
17	77 73412	9 89530	2 26723	71640	27725
18	87 14829	11 09370	2 54181	80316	31083
19	97 10041	12 36057	2 83208	89488	34633
20	107 59048	13 69592	3 13804	·99156	38374
21		15 09975	3 45969	1 09320	42307
22		16 57206	3 79703	1 19979	46433
23		18 11285	4 15006	1 31134	50750
24		19 72212	4 51878	1 42785	55259
25		21 39988	4·90319	1 54931	59959
26		23 14610	[illegible] 30329	1 67574	64852
27		24 96081	5 71908	1 80712	69937

Note G = Discharge in gallons per minute
d = Diameter of pipe in inches
H = Head in feet
L = Length of pipe in feet
m = A varying co-efficient the value of which varies only with diameter of the pipe.

FOUL PIPES—(*continued*)

Gallons per minute	Diameter of pipe in inches				
	1	1½	2	2½	3
	Value of *m*				
	015	0145	014	0135	013
	Head of water in feet				
[illegible]		26 84400	6 15056	1 94346	75213
29		28 79567	[illegible] 59773	2 08476	80681
30		30 81582	7 06059	2 23101	86342
31		32 90445	7 53914	2 38222	92194
32		35 06156	8 03338	2 53839	98237
33		37 28714	[illegible] 54331	2 699[illegible]2	1 04473
34		39 58121	9 06894	2 86[illegible]61	1 10901
35		41 94376	9 61025	3 03665	1 17520
36		44 37478	10 16725	3 21265	1 24332
37		46 87429	10 73994	3 39361	1 31335
38		49 44227	11 32832	3 570[illegible]3	1 38[illegible]30
39		52 07874	11 93240	3 77041	1 4[illegible]917
40		54 78368	12 55216	3 960[illegible]4	1 [illegible]3490
41		57 55710	13 18761	4 16703	1 61267
42		60 39901	13 83876	4 37278	1 69[illegible]20
43		63 30939	14 50559	4 58349	1 77384
44		66 [illegible]8825	15 18811	4 79915	1 8[illegible]730
45		69 33560	15 88633	5 01977	1 94208
46		72 45142	16 60023	5 24[illegible]3[illegible]	2 02098
47		75 63[illegible]72	17 32083	5 47589	2 11920
48		78 88850	18 07511	5 71139	2 21034
49		82 20976	18 83609	5 95184	2 30340
50		85 59950	19 61275	6 19725	2 39838
51			20 40511	6 44702	2 49[illegible]27
52			21 21315	6 7029[illegible]	2 59408
53			22 03689	6 96323	2 69481
54			22 87631	7 22847	2 79740
55			23 73143	7 49867	2 90203
56			24 60223	7 77383	3 00852
57			25 48873	8 05395	3 11693
58			26 39092	8 33902	3 22720
59			27 30879	8 6290[illegible]	3 339[illegible]0
60			28 24236	8 92104	3 45366
61			29 19162	9 22399	[illegible] 56974
62			30 15656	9 52889	3 68774
63			31 13720	9 83875	3 80766
64			32 13[illegible]3	10 15[illegible]7	[illegible] 92950
[illegible]			33 14555	10 47335	4 0[illegible]3[illegible]5
66			34 17326	10 79809	4 17893
67			35 21666	11 12778	4 30652
68			36 27574	11 46213	4 43603

FOUL PIPES—(*concluded*)

Gallons per minute	Diameter of pipe in inches				
	1	1½	2	2½	3
	Value of *m*				
	·015	·0145	·014	·013	·013
	Head of water in feet				
69			37 35052	11 80704	4 50747
70			38 44000	12 14661	4 70082
71			39 54715	12 49613	4 83608
72			40 66900	12 85062	4 97327
73			41 80654	13 21006	5 11238
74			42 95977	13 57446	5 25340
75			44 12869	13 94381	5 39634
76				14 31813	5 54121
77				14 69740	5 68709
78				15 08163	5 83669
79				15 47081	5 98730
80				15 86496	6 13984
81				16 26406	6 29430
82				16 66812	6 45067
83				17 07714	[illegible] 60896
84				17 49112	6 76917
85				17 91005	[illegible] 93130
86				18 33394	7 09535
87				18 76279	7 26132
88				19 19660	7 42921
89				19 63537	7 59901
90				20 07909	7 77074
91				20·52777	7 94438
92				20 98141	8 11994
93	...			21 44001	8 29742
94				21 90356	[illegible] 47682
95				22 37207	8 65813
96				22 84554	8 84137
97				23 32397	[illegible] 02652
98				23 80736	9 21360
99				24 29570	9 40259
100				24 78900	9·59350

TABLE XIV

Slightly Tuberculated.

Calculated by Baine's Slide Rule

Flamant's Formula $V = 76\ 28\ d^{\frac{5}{7}} s^{\frac{4}{7}}$ *

Discharge in gallons per minute	Diameter of pipe in inches									
	3½		4		4½		5		6	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
1										
2										
3										
4										
5	14									
6	20		11							
7	26		14		08					
8	33		17		10		06			
9	40		21		12		07			
10	48		26		15		09		04	
11	58		30		17		10		04	
12	67		35		20		12		05	
13	77		41		23		14		06	
14	82		46		27		16		07	
15	98		53		30		18		08	
16	1 12		59		33		20		09	
17	1 23		65		37		23		10	
18	1 35	72	73		41		25		10	
19	1 48	76	78		45		27		11	
20	1 64	80	87		49		30		13	
21	1 78	85	94		54		32		14	
22	1 92	[illegible]	1·02		58		35		15	
23	2 08	93	1 10	70	63		38		[illegible]	
24	2 25	97	1 20	74	67		41		17	
25	2 38	1 00	1 26	77	73		44		19	
26	2 55	1 04	1 36	80	78		48		20	
27	2 75	1·08	1 46	83	83		50		[illegible]	
28	2 94	1 13	1 55	86	89		53		23	
29	3 10	1 16	1 64	89	·95	71	57		[illegible]	
30	3 30	1 21	1·75	92	1·00	73	62		26	
31	3 50	1 24	1 86	·96	1 06	75	[illegible]		27	
32	3 65	1 28	1 96	[illegible]	1 12	78	·67		·29	

* V = Velocity in feet per second.
d = Diameter in feet
s = Sine of the inclination.

SLIGHTLY TUBERCULATED—(*continued*)

Discharge in gallons per minute	Diameter of pipe in inches									
	3½		4		4½		5		6	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
33	3 90	1 32	2 09	1 02	1 18	80	72		31	
34	4 10	1 36	2 18	1 04	1 24	83	76		32	
35	4 35	1 40	2 27	1 07	1 32	85	80		34	
36	4 55	1 45	2 38	1 10	1 37	87	83	71	35	
37	4 80	1 49	2 50	1 13	1 43	90	87	73	37	
38	4 95	1 53	2 67	1 17	1 52	92	92	75	39	
39	5 20	1 56	2 75	1 19	1 58	95	95	76	40	
40	5 35	1 58	2 86	1 22	1 65	97	99	78	41	
41	5 63	1 64	3 00	1 26	1 70	99	1 03	79	44	
42	5 90	1 68	3 10	1 27	1 77	1 02	1 07	82	45	
43	6 15	1 72	3 24	1 33	1 85	1 04	1 12	84	46	
44	6 30	1 75	3 29	1 34	1 93	1 06	1 17	86	50	
45	6 60	1 79	3 53	1 37	2 01	1 08	1 22	88	51	
46	6 78	1 82	3 68	1 41	2 09	1 11	1 26	90	53	
47	7 20	1 87	3 80	1 44	2 16	1 13	1 32	92	55	
48	7 40	1 91	3 95	1 47	2 25	1 16	1 37	94	58	
49	7 70	1 95	4 08	1 49	2 32	1 18	1 42	96	59	
50	7 85	1 99	4 19	1 52	2 40	1 21	1 46	97	62	
51	8 19	2 02	4 39	1 55	2 45	1 23	1 51	99	64	
52	8 30	2 06	4 49	1 58	2 58	1 25	1 56	1 02	66	70
53	8 70	2 11	4 70	1 62	2 66	1 27	1 63	1 04	68	72
54	9 00	2 15	4 85	1 64	2 71	1 29	1 68	1 06	71	73
55	9 30	2 18	4 95	1 67	2 85	1 32	1 72	1 07	73	75
56	9 [illegible]	2 23	5 15	1 71	2 92	1 34	1 78	1 09	75	76
57	9 80	2 25	5 21	1 73	2 98	1 37	1 84	1 12	77	77
58	10 10	2 30	5 40	1 76	3 08	1 38	1 89	1 14	80	79
59	10 30	2 33	5 52	1 78	3 18	1 42	1 95	1 15	82	80
60	10 70	2 37	5 65	1 82	3 26	1 44	2 00	1 16	85	81
61	11·00	2·41	5 95	1 86	3 39	1 46	2 06	1 18	87	82
62	11 40	2 45	6 05	1 87	3 50	1 49	2 12	1 21	90	84
63	11 60	2 50	6 30	1 93	3 58	1 52	2 17	1 23	92	85
64	11 90	2 54	6 45	1 95	3 70	1 54	2 25	1 25	95	87
65	12 30	2 57	6 53	1 97	3 75	1 55	2 30	1 26	97	88
66	12 60	2 62	6 74	2 00	3 86	1 57	2 36	1 28	1 01	89
67	13·00	2 65	6 90	2 04	4 00	1 61	2 41	1 31	1·03	91
68	13 50	2 70	7 15	2 07	4 05	1 63	2 46	1 33	1·06	92
69	13 75	2 74	7 30	2 10	4 20	1 66	2 55	1 34	1 08	93
70	14 10	2 78	7 55	2 14	4 30	1·68	2 62	1 36	1 10	94
71	14 40	2 82	7 70	2 16	4 42	1 71	2 66	1 37	1 14	96
72	14 90	2 87	7 85	2 18	4 50	1 73	2 75	1 41	1 16	98

TABLE XIV

Slightly Tuberculated.

Calculated by Barne's Slide Rule

Flamant's Formula $V = 76\ 28\ d^{\frac{5}{7}} s^{\frac{4}{7}}$ *

Discharge in gallons per minute	Diameter of pipe in inches									
	3½		4		4½		5		6	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head [illegible] thousand feet	Velocity feet per sec
1										
2										
3										
4										
5	14									
6	20		11							
7	26		14		08					
8	33		17		10		06			
9	40		21		12		07			
10	48		26		15		09		04	
11	58		30		17		10		04	
12	67		35		20		12		05	
13	77		41		23		14		06	
14	82		46		27		16		07	
15	98		53		30		18		08	
16	1 12		59		33		20		09	
17	1 23		65		37		23		10	
18	1 35	72	73		41		25		10	
19	1 48	76	78		45		27		11	
20	1 64	80	87		49		30		13	
21	1 78	85	94		54		[illegible]		14	
22	1 92	88	1·02		58		35		15	
23	2·08	93	1 10	70	63		38		16	
24	2 25	97	1 20	74	67		41		17	
25	2 38	1 00	1 26	77	73		44		19	
26	2 55	1 04	1 36	80	78		48		20	
27	2 75	1·08	1 46	83	[illegible]		50		21	
28	2 94	1 13	1 55	86	89		53		23	
29	3 10	1 16	1 64	89	·95	71	57		24	
30	3 30	1 21	1 75	92	1·00	73	[illegible]		26	
31	3 50	1 24	1 86	·96	1 06	75	64		27	
32	3 65	1 28	1 96	98	1 12	78	67		·29	

* V = Velocity in feet per second
d = Diameter in feet.
s = Sine of the inclination.

SLIGHTLY TUBERCULATED—(*continued*)

Discharge in gallons per minute	Diameter of pipe in inches									
	3½		4		4½		5		6	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
33	3.90	1.32	2.09	1.02	1.18	80	72		31	...
34	4.10	1.36	2.18	1.04	1.24	83	76		32	
35	4.35	1.40	2.27	1.07	1.32	85	80		34	
36	4.55	1.45	2.38	1.10	1.37	87	83	71	35	
37	4.80	1.49	2.50	1.13	1.43	90	87	73	37	
38	4.95	1.53	2.67	1.17	1.52	92	92	75	39	
39	5.20	1.56	2.[illegible]5	1.19	1.58	95	95	76	40	
40	5.35	1.58	2.86	1.22	1.65	97	99	78	41	
41	5.63	1.64	3.00	1.26	1.70	99	1.03	79	44	
42	5.90	1.68	3.10	1.27	1.77	1.02	1.07	82	45	
43	6.15	1.72	3.24	1.33	1.85	1.04	1.12	84	46	
44	6.30	1.75	3.29	1.34	1.93	1.06	1.17	86	50	
45	6.60	1.79	3.53	1.37	2.01	1.08	1.22	88	51	
46	6·78	1.82	3.68	1.41	2.09	1.11	1.26	90	53	
47	7.20	1.87	3.80	1.44	2.16	1.13	1.32	92	55	
48	7.40	1.91	3.95	1.47	2.25	1.16	1.37	94	58	
49	7.70	1.95	4.08	1.49	2.32	1.18	1.42	96	59	
50	7.85	1.99	4.19	1.52	2.40	1.21	1.46	97	62	
51	8.10	2.02	4.39	1.55	2.45	1.23	1.51	99	64	
52	8.30	2.06	4.49	1.58	2.58	1.25	1.56	1.02	66	70
53	8.70	2.11	4.70	1.62	2.66	1.27	1.63	1.04	68	72
54	9.00	2.15	4.85	1.64	2.71	1.29	1.68	1.06	71	73
55	9.30	2.18	4.95	1.67	2.85	1.32	1.72	1.07	73	75
6	9.65	2.23	5.15	1.71	2.92	1.34	1.78	1.09	75	76
57	9.80	2.25	5.21	1.73	2.98	1.37	1.84	1.12	77	77
58	10.10	2.30	5.40	1.76	3.08	1.38	1.89	1.14	80	79
59	10.30	2.33	5.52	1.78	3.18	1.42	1.95	1.15	82	80
60	10.70	2.37	5.65	1.82	3.26	1.44	2.00	1.16	85	81
61	11·00	2·41	5.95	1.86	3.39	1.46	2.06	1.18	87	82
62	11.40	2.45	6.05	1.87	3.50	1.49	2.12	1.21	90	84
63	11.60	2.50	6.30	1.93	3.[illegible]8	1.52	2.17	1.23	92	85
64	11.90	2.54	6.45	1.95	3.70	1.54	2.25	1.25	95	87
65	12.30	2.57	6.53	1.97	3.75	1.55	2.30	1.26	97	88
66	12.60	2.62	6.74	2.00	3.86	1.57	2.36	1.28	1.01	89
67	13.00	2.65	6.90	2.04	4.00	1.61	2.41	1.31	1.03	91
68	13.50	2.70	7.15	2.07	4.05	1.63	2.46	1.33	1·06	92
69	13.75	2.74	7.30	2.10	4.20	1.66	2.55	1.34	1.08	93
70	14.10	2.78	7.55	2.14	4.30	1·68	2.62	1.36	1.10	94
71	14.40	2.82	7.70	2.16	4.42	1.71	2.66	1.37	1.14	96
72	14.90	2.87	7.85	2.18	4.50	1.73	2.75	1.41	1.16	·98

SLIGHTLY TUBERCULATED—(*continued*)

Discharge in gallons per minute	Diameter of pipe in inches: 3½ — Loss of head per thousand feet	3½ — Velocity feet per sec	4 — Loss of head per thousand feet	4 — Velocity feet per sec	4½ — Loss of head per thousand feet	4½ — Velocity feet per sec	5 — Loss of head per thousand feet	5 — Velocity feet per sec	6 — Loss of head per thousand feet	6 — Velocity feet per sec
73	15.25	2.91	8.15	2.25	4.60	1.76	2.81	1.43	1.18	09
74	15.60	2.95	8.30	2.26	4.75	1.78	2.89	1.44	1.22	1.01
75	16.15	3.00	8.55	2.29	4.85	1.80	2.95	1.46	1.26	1.02
76	16.50	3.04	8.70	2.32	4.95	1.82	3.01	1.48	1.28	1.03
77	16.90	3.07	8.90	2.34	5.05	1.84	3.10	1.50	1.31	1.04
78	17.20	3.13	9.20	2.38	5.20	1.87	3.15	1.52	1.34	1.06
79	17.50	3.14	9.30	2.40	5.32	1.90	3.25	1.54	1.37	1.07
80	17.90	3.17	9.50	2.43	5.45	1.92	3.29	1.55	1.39	1.08
81	18.25	3.21	9.80	2.46	5.58	1.95	3.40	1.57	1.42	1.09
82	18.80	3.26	9.90	2.49	5.68	1.96	3.45	1.59	1.45	1.11
83	19.10	3.30	10.20	2.52	5.78	1.99	3.48	1.61	1.49	1.13
84	19.60	3.35	10.40	2.55	5.90	2.03	3.58	1.63	1.51	1.14
85	20.10	3.39	10.60	2.57	6.00	2.04	3.68	1.66	1.55	1.15
86	20.50	3.42	10.80	2.62	6.20	2.06	3.75	1.68	1.57	1.16
87	20.90	3.46	10.95	2.64	6.30	2.09	3.85	1.70	1.61	1.17
88	21.40	3.52	11.20	2.67	6.40	2.11	3.91	1.72	1.65	1.18
89	21.80	3.55	11.40	2.71	6.55	2.14	3.95	1.73	1.68	1.20
90	22.20	3.59	11.60	2.74	6.65	2.16	4.08	1.76	1.72	1.22
91	22.60	3.64	11.90	2.78	6.80	2.18	4.13	1.77	1.74	1.23
92	23.00	3.67	12.15	2.81	6.90	2.21	4.20	1.79	1.76	1.24
93	23.50	3.72	12.40	2.83	7.05	2.23	4.29	1.81	1.82	1.26
94	23.80	3.75	12.60	2.86	7.20	2.26	4.40	1.83	1.85	1.28
95	24.50	3.80	12.80	2.89	7.35	2.29	4.48	1.85	1.89	1.29
96	24.90	3.84	13.20	2.92	7.49	2.31	4.55	1.87	1.92	1.30
97	25.40	3.88	13.35	2.95	7.60	2.33	4.65	1.89	1.96	1.32
98	25.75	3.92	13.60	2.98	7.70	2.35	4.70	1.92	1.98	1.33
99	26.40	3.96	13.95	3.02	7.80	2.37	4.82	1.94	2.01	1.34
100	26.85	4.00	14.20	3.06	7.90	2.40	4.89	1.95	2.06	1.36
110	31.95	4.41	16.65	3.37	9.50	2.65	5.78	2.15	2.44	1.49
120	37.20	4.81	19.60	3.68	11.10	2.90	6.75	2.35	2.85	1.63
130	43.00	5.22	22.50	3.98	12.70	3.14	7.75	2.55	3.23	1.76
140			25.80	4.30	15.50	3.38	8.58	2.74	3.70	1.89
150			29.40	4.62	16.50	3.64	9.90	2.93	4.17	2.03
160			33.00	4.92	18.40	3.87	11.20	3.13	4.65	2.16
170			36.50	5.23	20.06	4.12	12.50	3.32	5.22	2.32
180					22.80	4.37	13.70	3.53	5.73	2.45
190					25.20	4.62	15.15	3.73	6.30	2.58
200					27.50	4.85	16.65	3.93	6.90	2.72
210					30.03	5.10	18.10	4.13	7.55	2.85
220						–	19.80	4.33	8.20	2.99

SLIGHTLY TUBERCULATED—(*continued*)

Discharge in gallons per minute	Diameter of pipe in inches									
	3½		4		4½		5		6	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
230							21 50	4 53	8 90	3 14
240							23 00	4 72	9 70	3 27
250							24 80	4 90	10 04	3 40
260							26 60	5 12	11 11	3 55
270									11 80	3 69
280									12 65	3 82
290									13 50	3 96
300									14 40	4 10
310									15 20	4 25
320									16 00	4 38
330									17 00	4 52
340									17 90	4 66
350									18 95	4 80
360									20 00	4 93
370									21 00	5 06

SLIGHTLY TUBERCULATED—(*continued*)

Discharge in gallons per minute	Diameter of pipe in inches: 7		8		9		10		12	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
20	06		03							
30	12		06		03					
40	20		10		06		03			
50	29		15		09		05			
60	41		21		12		07		03	
70	53	70	28		16		09		04	
80	67	79	36		20		12		05	
90	82	90	44		25		15		06	
100	98	·99	53	76	30		18		07	
110	1 17	1·09	62	84	35		21		09	
120	1 36	1 18	72	92	41	72	25		10	
130	1 55	1 28	83	99	47	78	28		12	
140	1 75	1 38	95	1 07	53	84	32		13	
150	2 00	1 49	1 08	1 15	61	90	37	73	15	
160	2 22	1 58	1 18	1 22	67	96	41	78	17	
170	2 46	1 68	1 33	1 29	76	1 03	45	82	19	
180	2 75	1 78	1 46	1 36	84	1 08	51	88	21	
190	3 01	1 88	1 60	1 45	92	1 14	55	92	23	
200	3 30	1 98	1 76	1 52	1 00	1 20	60	97	25	
210	3 58	2 08	1 91	1 60	1 09	1 26	66	1 01	28	71
220	3 89	2 18	2 09	1 68	1 19	1 32	72	1 07	30	75
230	4 23	2 29	2 26	1 76	1 29	1 38	77	1 12	33	78
240	4 55	2 38	2 42	1 82	1 39	1 45	83	1 16	35	81
250	4 90	2 48	2 60	1 91	1 49	1 50	90	1 22	38	84
260	5 26	2 59	2 79	1 99	1 59	1 57	97	1 27	40	88
270	5 68	2 69	2 99	2 06	1 68	1 63	1 02	1 32	43	91
280	6 00	2 80	3 09	2 14	1 80	1 68	1 10	1 37	47	95
290	6 40	2 90	3 40	2 22	1 93	1 75	1 16	1 42	49	98
300	6 80	2 99	3 60	2 30	2 05	1 81	1 24	1 46	52	1 02
310	7 24	3 10	3 82	2 38	2 17	1 87	1 32	1 52	55	1 06
320	7 65	3 20	4 04	2 46	2 29	1 93	1 38	1 56	58	1 09
330	8 20	3 31	4 30	2 53	2 42	1 99	1 46	1 62	62	1 12
340	8 55	3 41	4 55	2 61	2 55	2 06	1 54	1 66	65	1 16
350	9 00	3 51	4 78	2 68	2 68	2 12	1 62	1 71	67	1 19
360	*9 50*	*3 61*	*5 00*	*2 76*	*2 82*	*2 17*	*1 69*	*1 76*	72	*1 22*
370	9 90	3 70	5 25	2 84	2 96	2 23	1 78	1 80	75	1 25
380	10 34	3 82	5 55	2 92	3 13	2 30	1 86	1 85	78	1 28
390	10 88	3 90	5 78	2 98	3 25	2 36	1 95	1 89	82	1 32
400	11 40	4 00	6 00	3 06	3 39	2 41	2 05	1 95	86	1 35
410	11·90	4 10	6 30	3 14	3 53	2 47	2 14	2 00	90	1 38

SLIGHTLY TUBERCULATED—(continued)

Discharge in gallons per minute	Diameter of pipe in inches									
	6		8		9		10		12	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
420	12.40	4.22	6.60	3.22	3.72	2.54	2.23	2.05	.95	1.43
430	13.00	4.32	6.95	3.30	3.88	2.61	2.32	2.10	.98	1.46
440	13.55	4.42	7.25	3.38	4.07	2.67	2.41	2.16	1.02	1.49
450	14.10	4.52	7.40	3.47	4.21	2.73	2.52	2.20	1.07	1.53
460	14.00	4.63	7.65	3.54	4.40	2.79	2.63	2.25	1.12	1.56
470	15.20	4.73	8.00	3.61	4.53	2.84	2.73	2.29	1.15	1.59
480	15.75	4.83	8.[illegible]0	3.68	4.72	2.91	2.83	2.34	1.19	1.63
490	16.30	4.92	8.64	3.76	4.90	2.97	2.94	2.39	1.27	1.66
500	16.90	5.02	8.90	3.84	5.00	3.03	3.05	2.44	1.29	1.70
510			9.30	3.92	5.25	3.08	3.15	2.49	1.32	1.73
520			9.65	4.00	5.41	3.15	3.29	2.54	1.38	1.77
530			9.90	4.07	5.61	3.21	3.39	2.58	1.[illegible]	1.81
540			10.23	4.15	5.82	3.27	3.49	2.63	1.47	1.84
550			10.67	4.23	6.00	3.32	3.60	2.68	1.52	1.87
560			11.00	4.30	6.20	3.39	3.72	2.73	1.57	1.91
570			11.40	4.38	6.45	3.45	3.87	2.79	1.62	1.94
580			11.70	4.48	6.70	3.52	3.90	2.84	1.68	1.98
590			12.00	4.54	6.80	3.58	4.10	2.88	1.73	2.02
600			12.35	4.62	7.00	3.63	4.25	2.93	1.77	2.04
610			12.80	4.70	7.23	3.69	4.38	2.98	1.83	2.07
620			13.20	4.78	7.45	3.75	4.50	3.03	1.89	2.12
630			13.50	4.84	7.70	3.83	4.61	3.09	1.94	2.15
640			14.00	4.94	7.90	3.89	4.75	3.14	2.00	2.19
650			14.30	5.00	8.15	3.94	4.89	3.18	2.04	2.22
660					8.30	4.00	5.01	3.23	2.10	2.25
670					8.55	4.06	5.14	3.27	2.16	2.28
680					8.80	4.12	5.29	3.32	2.21	2.32
690					9.00	4.19	5.41	3.38	2.28	2.35
700					9.25	4.25	5.58	3.43	2.35	2.39
710					9.50	4.31	5.72	3.48	2.40	2.42
720					9.78	4.38	5.85	3.53	2.45	2.45
730					10.00	4.44	6.00	3.58	2.52	2.49
740					10.30	4.52	6.20	3.63	2.59	2.53
750					10.[illegible]0	4.60	6.30	3.68	2.65	2.56
760					10.75	4.63	6.45	3.72	2.72	2.60
770					11.00	4.68	6.65	3.78	2.77	2.62
780					11.25	4.75	6.78	3.84	2.84	2.67
790					11.45	4.81	6.90	3.88	2.90	2.69
800					11.75	4.85	7.05	3.92	2.96	2.73
810					11.95	4.91	7.20	3.98	3.03	2.76
820					12.30	4.98	7.35	4.03	3.10	2.80

SLIGHTLY TUBERCULATED—(*concluded*)

Discharge in gallons per minute	Diameter of pipe in inches									
	7		8		9		10		12	
	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec	Loss of head per thousand feet	Velocity feet per sec
830					12 55	5 05	7 55	4 0[illegible]	3 18	2 83
840							7 70	4 13	3 23	2 86
850							7 85	4 18	3 30	2 89
860							8 00	4 23	3 37	2 93
870							8 20	4 28	3 45	2 96
880							8 35	4 32	3 50	3 00
890							8 50	4 36	3 58	3 04
900							8 70	4 42	3 67	3 08
910							8 85	4 48	3 72	3 11
920							9 00	4 5[illegible]	3 80	3 14
930							9 23	4 57	3 89	3 18
940							9 40	4 61	3 95	3 21
950							9 60	4 67	4 02	3 24
960							9 75	4 71	4 10	3 28
970							9 90	4 76	4 19	3 31
980							10 12	4 82	4 29	3 35
990							10 35	4 87	4 38	3 38
1000							10 50	4 91	4 45	3 42
1050							11 40	5 16	4 80	3 58
1100									5 24	3 76
1150									5 68	3 94
1200									6 15	4 13
1250									6 60	4 28
1300									7 05	4 45
1350									7 50	4 63
1400									8 00	4 80
1450									8 50	4 96
1500									9 00	5 14

TABLE XV

Strains on Tie-rods, &c., in Arched Roofs.

Arch		Inclination of Tangent with Horizon	Strains on Tie rods in lbs			Length of arc in feet
Span feet	Rise feet		Rods 1 foot apart	Rods 2 feet apart	Rods 3 feet apart	
7½	1½	37°34	588	1 176	1 763	9 04
[illegible]	1½	36° 1	649	1 298	1 949	9 45
9	1½	33°13	786	1 572	2 359	10 20
10	2	37 33	768	1 535	2 303	11 80
12	2½	38 32	868	1 735	2 603	13 81
12	3	42°47	801	1 601	2 402	14 84
14	3	39°12	1 006	2 012	3 018	16 42
16	4	42°48	1 052	2 103	3 155	19 47
18	4½	42°48	1 177	2 353	3 530	21 70
20	4½	40°21	1 379	2 759	4 138	23 44
24	5	38 32	1 725	3 450	5 175	27 47
24	6	42°48	1 552	3 104	4 656	28 74
30	6	37°34	2 202	4 404	6 606	33 86
30	7	41°12	2 014	4 028	6 042	35 26

Arched Roofs—These roofs have been calculated with circumscribing arc outside 6 inches of brickwork The line of thrust is tangential to the parabola, of which the vertex coincides with the upper 60° of the arc 60° is too flat but is usually adopted to save calculations

EXAMPLES.

Examples will now be given of the calculations most usually required.

Weights on Foundations.

The calculation of weight on a foundation being simply an enumeration of the various superincumbent weights, and a reduction of the result to the weight borne by a square foot of the foundation, an Example is unnecessary. The results should not exceed, and should as nearly as possible equal, the weights given in Table II; but even within the limits therein given, no large disproportion should exist between the maximum and minimum pressures under two different parts of the same structure on the same soil. In submitting calculations, these extreme pressures should be worked out and compared. Intermediate pressures may be omitted.

Floorings.

Example I.

An upper story hospital flooring is to be constructed with double 1½ inch teak planking, each plank being 4½ inches wide, with felt between, laid on sal wood joists, the joists being supported on either rolled steel beams or built up girders across the building. The girders are 6 feet, and the joists 2 feet, apart, from centre to centre. The building is 24 feet wide internal measurement. The weight of the felt may be neglected.

To find whether the planking is thick enough (this is given for purposes of proof and as an example. It will not generally be necessary to enter into calculations for thickness of planking).

Suppose the planks not to break joint in their width which would be a weaker construction than if they do break joint. Let W = the Load on a single plank, uniformly distributed.

Then total load on two planks
$= 2 \times \frac{3}{8} \times 112$ (Table I)
$+ 2 \times \frac{3}{8} \times \frac{1}{4} \times 52$ (Table III)
$= 84 + 9.75 = 93.75$

and $W = \frac{93.75}{2} = 46.875$

In Deflection—From Formula III—

For teak $bd^3 = \frac{WL^2}{320}$

Here $b = 4.5$, $L = 2$, $W = 47$,

$bd^3 = \frac{47 \times 2^2}{320} = .59$

From Table VII it is evident planks are amply strong enough

Joists

$W = 6 \times 2 \times 112 + 6 \times 2 \times \frac{1}{4} \times 52 + 6 \times$ (say) $\frac{3\frac{1}{2} \times 5}{144} \times 62$, (Table III)
$= 1344 + 156 + 45.2 = 1545.2$ lbs
$L = 6$ feet

log 1545.2	= 3.18898
log 36	= 1.55630
	4.74528
log 330	= 2.51851
log bd^3 = log 168	= 2.22677

In Deflection—From Formula III—

For sal $bd^3 = \frac{WL^2}{330} = \frac{1545.2 \times 6^2}{330} = 168$

See Table VII, and $b = 2''$, $d = 4\frac{1}{2}$ will do

log 1545.2	= 3.18898
log 6	= .77815
	3.96713
log 250	= 2.39794
log bd^2 = log 37	= 1.56919

In Transverse stress—From Formula III—

For sal $bd^2 = \frac{WL}{250} = \frac{1545.2 \times 6}{250} = 37$

See Table VIII, $b = 2''$, $d = 4\frac{1}{2}''$ will do

Make joists therefore $2'' \times 4\frac{1}{2}''$*

Note—*It is generally sufficient to calculate joists having a breadth of 2 inches for transverse stress only*

Girder

It will generally be cheaper to use a rolled steel beam than to build up a girder.

*It can be proved that when the same timber is used for boards and joists a floor is most economically designed for deflection when the amount of timber in the planking is one-half that in the joists. The same remark applies to a planked roof on common rafters

$L = 24$

$W = 24 \times 6 \times 112 + 24 \times 6 \times \frac{1}{4}$
$\times 52$ + weight of rolled beam, (weight of joists may be neglected)

$= 16128 + 1872$ + weight of girder

$= 18000 +$ weight of girder

See Table XI

For Load

log 18000 = 4 25527
log 24 = 1 38021
= 5 63548
log 2240 = 3 35024
log K = log 192 = 2 28524

(*i*) $W \times L = \frac{18000 \times 24}{2240}$ (for trial)
$= 192$

Select a beam $10 \times 6 \times 42$ lbs having
$K = 211\ 614$

Then $W = 18000 + 42 \times 24 = 19008$
$= 8\ 5$ tons

and $\frac{K}{L} = \frac{211\ 614}{24} = 8\ 8$ which is greater than W

(*ii*) *For Deflection*

$\frac{WL^2}{100} = \frac{19008 \times 24^2}{2240 \times 100} = 49$ which is greater than K_1 for this section Therefore the beam is not strong enough A beam 16″ × [illegible] × 42lbs having $K_1 = 69\ 473$ must be used

---

NOTE —If the ends of the girders are built into the walls the beam may be regarded as "fixed"

EXAMPLE II

An upper flooring for a double storied barrack is to be laid with $1\frac{1}{2}$ inch flagging on 22 ⊥ steel joists, the flanges of the ⊥ steels being downwards, and the intervals between the webs being filled with bricks. The ⊥ steels to be supported on rolled steel beams at 6 feet intervals from centre to centre, extending across the building, which is 24 feet wide, internal measurement. The ⊥ steel joists to be calculated for clear spans, not from the centre of the girders—in this instance (say) 65 inches.

<u>⊥-steel joists.</u>

There being 22 joists, there will be 23 spaces, each of $\frac{24}{23}$ of a foot. This will just give room for the spaces to be filled in with foot bricks, the spaces being 1′ $0\frac{1}{2}$″ (nearly) measuring from centre to centre.

Live load $= 6 \times \frac{24}{23} \times 112$, (Table I)
$= 701$ lbs.

Weight of flagging $= 6 \times \frac{24}{23} \times \frac{1}{8} \times 156$ (Table III)
$= 122.1$ lbs.

" " bricks $= 6 \times \frac{12\frac{1}{2}}{12} \times \frac{2\frac{1}{2}}{12} \times 120$, (Table III)
$= 159.1$ lbs.

The total load exclusive of weight of ⊥ steel joist
$= 701 + 122.1 + 159.1$
$= 982$ lbs. $= .44$ tons.

Try a ⊥ steel 3″ × 3″ × 312 (Table IX)
$K = W \times L$

For Load.—

Here W = .45 tons including weight of joist

and $L = \frac{65}{12} = 5.41$ feet.

$\frac{K}{L} = \frac{2.81}{5.41} = .52$ which is greater than W.

For Deflection—$\frac{WL^2}{100} = \frac{\cdot 45 \times 5\ 41^2}{100} = 1317$

which is less than K_1 for this section

Make joists therefore 3" × 3" × 312"

Girders

Live load = 24 × 6 × 112

= 16, 128 lbs

Weight of flagging = 24 × 6 × ½ × 156

= 2,808 lbs

" " bricks = 23 × 159 1 (from above)

= 3,660 lbs

" " ⊥ steels = 22 × 36

= 792 lbs

Then total load exclusive of weight of steel girder

= 16128 + 2808 + 3660 + 792

= 23388 lbs = 10 45 tons

Then W × L = 10 45 × 24 = 250 8

Try a section 15" × 5" × 42 lbs having K = 285 471 (Table XI)

Weight of such a beam = 42 × 24

= 1008 lbs = 45 tons

∴ total weight = 10 45 + 45

= 10 9 tons

and W × L = 10 9 × 24

= 261 6 tons

Then for *load* $\frac{K}{L} = \frac{285\ 471}{24} = 11\ 9$,

which is greater than W, and for *deflection* $\frac{WL^2}{100} = \frac{10\ 9 \times 24^2}{100} = 62\ 7$.

This is greater than value for K_1 for this section and a larger section must therefore be used.

A further calculation shows that a section 14" × 6" × 57 lbs must be used

Make therefore 14" × 6" *weighing* 57 *lbs per foot run.*

NOTE —See note at bottom of page 130

Roofs.

EXAMPLE III KING-POST TRUSS (*Plate* I)

A roof is to be constructed with a King-post Truss, the clear span being 24 feet The trusses to be $6\frac{3}{4}$ *feet apart and the common rafters* $2\frac{1}{4}$ *feet apart, each from centre to centre Timber sâl wood Roof covering to be double Allahabad tiling, on battens 1 foot apart from centre to centre Slope of roof 26° 35, or 1 in 2 Walls 18 inches thick*

Then Span of Truss $= 24 + 2\left(\frac{1}{2} \times 1\frac{1}{2}\right) = 25\frac{1}{2}$ *feet*

(*See Plate* I, *Fig* 1)

Construction of Diagram

Make AB = $25\frac{1}{2}$ feet

Bisect AB in D

Erect perpendicular DC, making DC = $\frac{1}{4}$ AB

Bisect AC and BC in E and F

Join ED and FD

Battens

Weight of double Allahabad tiling reduced to normal	= 30 lbs (Table III)
Allowance for work people (normal to a roof sloping $\frac{1}{2}$)	= 17 lbs (equivalent to 19 lbs vertical, page 96)
Total,	= 47 lbs per s ft

W = 1 × $2\frac{1}{4}$ × 47 = 105·75 lbs

L = 2·25 feet

Deflection—*See* Formula III —

For sâl $bd^3 = \frac{WL^2}{330} = \frac{105 \cdot 75 \times 2 \cdot 25^2}{330}$

= 1·62

From Table VII it is seen that $b = 1''$ $d = 1\frac{1}{4}''$ will do

Transverse stress—*See* Formula III —

For sâl $bd^2 = \frac{WL}{250} = \frac{105 \cdot 75 \times 2 \cdot 25}{250} = \cdot 95$

From Table VIII it is seen that $b = 1$, $d = 1$ will do, a less result than before

log 2·25	= 0·35218
	2
	0·70436
log 105·75	= 2·02428
	2·72864
log 330	= 2·51851
log 1·62	= 0·21013
log 2·25	= 0·35218
log 105·75	= 2·02428
	2·37646
log 250	= 2·39794
log ·95	= $\bar{1}$·97852

** *Make battens therefore* $1'' \times 1\frac{1}{4}''$.

N.B.—*In almost all cases it will be sufficient to calculate battens by the deflection formula only.*

Common Rafters

$W = 7.118 \times 2.25 \times 47 = 753$ lbs (The weight of the framing or roof timbers may always be safely omitted, it makes no *practical* difference, and the calculation is troublesome.)

Deflection—Formula III —

log 7.118	= 0.85240	
	2	
	1.70480	
log 753	= 2.87679	
	4.58159	
log 330	= 2.51851	
log 115.6	= 2.06308	

For sal $bd^3 = \frac{WL^2}{330} = \frac{753 \times 7.118^2}{330}$
$= 115.6$

From Table VII it is seen that $b = 2''$, $d = 4$ will do.

To inverse stress—Formula III —

log 7.118	= 0.85240	
log 753	= 2.87679	
	3.72919	
log 250	= 2.39794	
log 21.4	= 1.33125	

For sal $bd^2 = \frac{WL}{250} = \frac{753 \times 7.118}{250}$
$= 21.4$

From Table VIII it is seen that $b = 2$, $d = 3\frac{1}{2}$ will do, a less result than before.

** *Make common rafters* 2×4.

*N.B.—*In almost all cases it will be sufficient to calculate common rafters by the deflection formula only.*

Purlins

$W = 6.75 \times 7.118 \times 47 = 2258$ lbs (*see* remarks under common rafters)

Deflection—Formula III —

log 6.75	= 0.82930	
	2	
	1.65860	
log 2258	= 3.35372	
	5.01232	
log 330	= 2.51851	
log 311.8	= 2.49381	

For sal $bd^3 = \frac{WL^2}{330} = \frac{2258 \times 6.75^2}{330}$
$= 311.8$

From Table VII it is seen that $b = 3\frac{1}{2}''$, $d = 4\frac{1}{2}$ will do.

* It can be proved theoretically that a roof is most economically designed when the amount of timber in the battens is one-third of that in the common rafters. If the proportion be in excess of this the rafters should be spaced closer together, if less further apart.

** Note.—Calculations should however be made using Formula III for permanent load only (tiling) as these give larger results, viz., Battens $1\frac{1}{4}'' \times 1\frac{1}{4}''$, Common Rafters $2\frac{1}{2}'' \times 4\frac{1}{2}''$, Purlins $3\frac{1}{2}'' \times 5''$.

Transverse stress—Formula III —

For sal $bd^2 = \frac{WL}{250} = \frac{2258 \times 6\ 75}{250}$

$= 61$

log 6 75	=0 82930
log 2258	=3 35372
	4 18302
log 250	=2 39794
log 61	=1 78508

From Table VIII it is seen that $b = 3\frac{1}{2}$ $d = 4\frac{1}{2}''$ will do, a smaller result than before

** *Make purlins* $3\frac{1}{2}'' \times 4\frac{1}{2}''$.

N B —*In almost all cases it will be sufficient to calculate purlins by the deflection formula only*

Principal Rafters

Weight of double Allahabad tiling } =34 lbs (Table III)

Allowance for work people } =19 lbs (page 96)

Total =53 lbs

Then Formula VII(a)—

$P = \left(\frac{13}{16} W + \frac{w}{2}\right)$ cosec θ

Now as W is partly made up of allowance for work people this formula gives a result slightly in excess of the truth, and thus, except when a ceiling is attached to the tie-beam, *w* may always be safely neglected

The above formula then in present instance becomes

$P = \frac{13}{16} W$ cosec $26^\circ 35 = 1\ 82$ W.

$W = 14\ 23 \times 6\ 75 \times 53 = 5090$ lbs

(The weight of the framing may in cases of Allahabad tiled roofs be safely neglected)

Then $P = 1\ 82 \times 5090 = 9{,}264$ lbs

Formula V —When length is between

** NOTE.—Calculations should however be made using Formula III for permanent load only (Tiling) as these give larger results etc., Battens $1\frac{1}{2}'' \times 1\frac{1}{2}''$ Common Rafters $2\frac{1}{2}'' \times 4\frac{1}{2}$, Purlins $3\frac{1}{2}'' \times 3''$

12 and 24 times least sectional dimension

$$S = \frac{2P}{c}$$

For sal, $c = 1210$ (Table IV)

Then $S = \frac{2 \times 9264}{1210} = 15.3$ sq inches

Make principal rafters 3" × 5¼"

Round bar Tie Rod (if used instead of a wooden tie beam)

Formula VII(*b*)—

$P = \frac{13}{16}$ W cot θ (neglecting w)

$= \frac{13}{16}$ W cot 26° 35' $= 1.62$ W,

$= 1.62 \times 5090$ (*see* above),

$= 8,246$ lbs

And $P = S \times t$ (Formula IV)

For steel, $t = 14000$ (Table IV)

and $S = \pi r^2$,

diameter $= 2r = \sqrt{\frac{8246 \times 4}{3.1416 \times 14000}}$

$= .86$

log 8246	= 3.91624
log 4	= 0.60206
log numerator	= 4.51830
log 3.1416	= 0.49715
log 14000	= 4.14612
log denominator	= 4.64327
Subtract	2)$\bar{1}$.87503
log .86	$\bar{1}$.93751

Make tie-rod ⅞" diameter

Abstract of Scantlings

Battens	1¼" × 1¼"
Common rafters	2¼" × 4¼"
Purlins	3½" × 5"
Principal rafters	3" × 5¼"
Tie-beams	3 × 5¼"
Struts	3 × 3
Straps, steel, at foot of principal rafter	1½" × ¼
Bolts do do	1½ diam
Straps at head and foot of king post	1½ × ¼
Bolt do do	1
King post (double)	5¼" × 2

EXAMPLE IV QUEEN POST TRUSS (*Plate* I)

A roof is to be constructed with a Queen post Truss. The clear span is 30 feet. The trusses are to be 6¾ feet apart. Timber, sal wood. Roof covering to be double Allahabad tiling, on battens 1 foot apart from centre to centre, resting directly on the principal rafters. Slope of roof 26° 35′, *or 1 in 2. Walls 18 inches thick*

(*N B* —This style of construction, viz, with battens resting direct on principal rafters, is not recommended, particularly with a Queen post truss, but is merely given for the sake of example, as it is sometimes adopted with a King post truss)

Span of Truss = 30 + 2 (½ × 1½) = 31½ *feet*

(*See Plate* I, *Fig* ii)

__*Construction of Diagram*__

Make AB = 31½ feet
Bisect AB in D
Erect perpendicular DC, making DC = ¼ AB
Join AC and BC
Trisect AC and BC in E, F, and G, H
Join FG and drop perpendiculars FI and GK
Join FI and KH

__*Battens*__

Weight of double Allahabad tiling reduced to normal		= 30 lbs
Allowance for work people, normal	=22 3 lbs (equivalent to 25 lbs vertical, page 95)	

Total = 52 3 lbs per s ft

Deflection—Formula III —

For sal $bd^3 = \frac{WL^2}{330}$

W = 52 3 × 1 × 6 75 = 353 lbs

L = 6 75

$bd^3 = \frac{353 \times 6\ 75^2}{330} = 48\ 7$

log 6 75 = 0·82930
2
1 65860
log 353 = 2 54777
4 20637
log 330 = 2 51851
log 48 7 = 1 68786

From Table VII

$b = 2$, $d = 3$ A section 2½ × 3 is however required by the formula for permanent load

Principal Rafters

Weight of Allahabad tiling and allowance for work people = 59 lbs per square foot

Formula VIII (a)—

$$P = \left(\frac{5}{6} W + \frac{t}{2}\right) \operatorname{cosec} \theta$$

This formula, with an allowance for work people included in W, gives a result somewhat larger than the true one as there is no ceiling on the beam t may be neglected, so may weight of framing

log 1 88	= 0 2741o
log 6970	= 3 84323
log 13 100	= 4 11738

Then W = 59 × 17 5 × 6 75
= 6970 lbs

and $P = \frac{5}{6} \times 6970 \times$ cosec 26° 35
= 1 88 × 6970
= 13,100 lbs

The principal rafters are supported laterally by battens at 1 foot central intervals so that length is between 1 and 8 times least sectional dimension, and from Formula V,

$$P = S \times c$$

For sal, $c = 1210$ (Table IV)

Then $S = bd$ = $\frac{13\,100}{1210}$ 10 8 (i)

Transverse stress—Formula III—

For sal $bd^2 = \frac{WL}{250}$

log 2047	= 3 31111
log 5 8	= 0 76342
	4 07453
log 250	= 2 39794
log 47 4	= 1 67659

W = 5 8 × 6 75 × 52 3 = 2047 lbs

L 5 8

$$bd^2 = \frac{2047 \times 5\,8}{250} = 47\,4$$

Now

b=1 8", d=6 satisfies equation (i)

b=1 32, d=6 " " (ii)

Add the two values of b, and make principal rafters $3\frac{1}{4}$ × 6 .

N.B.—*For the theory involved in the above method, see "Roorkee Manual of Applied Mechanics," Vol. I., pages 281—287.*

Strap and bolt at foot of principal rafter

Formula VIII (*b*) neglecting w,

Tension on tie beam $= \frac{5}{6}$ W cot θ

$= \frac{5}{6} \times 6970 \times \cot 26° 35$

$= 1.66 \times 6970 = 11{,}570$ lbs.

log 1.66	= 0.22010
log 6970	= 3.84323
log 11570	= 4.06333

Formula IX. Section of heel strap

$= \frac{P}{2t} = \frac{11570}{2 \times 14000}$ (Table IV)

Then S = 0.413 square inch

Make strap 1¾″ × ¼″

From Formula X—

Diameter of bolt $= \frac{\text{tension on tie beam}}{b \times \frac{1}{6} c}$

Here tension on tie-beam = 11,570 lbs.

b = breadth of principal rafter,

= 3½ inches

c = 1210, sal (Table IV)

Diameter of bolt $= \frac{11570}{3\frac{1}{2} \times 2000} = 1.7$ inches

Make bolt 1¾″ diameter

Abstract of Scantlings

Battens	2½″ × 3″
Principal rafters	3½″ × 6″
Tie beam	3½″ × 6″
Struts	3½″ × 3½″
Queen posts	6″ × 1½″ (double)
Straining beam	3½″ × 6″
Straining sill	2″ × 3½″
Straps at heel of principal rafter	1¾″ × ¼
Bolts do. do.	1¾″ diam
Bolts elsewhere	1⅛″ ″
Straps at feet of Queen posts	1¾″ × ¼″

Example V (*Plate* II)

A Steel Truss over a clear span of 24 feet

A roof is to be constructed over a Barrack with a clear internal span of 24 feet, the truss to be of the form shown in the diagram, and the shape to be as described in the "Construction of Diagram" below The trusses to be at [illegible]¾ feet intervals, and the purlins, common rafters, and battens to be of sal wood the common rafters being 2¼ feet apart from centre to centre The principal rafters to be of ┳ *steel, the struts of double flat steel bars and all the tie bars of flat steel The roof covering to be of double Allahabad tiling, and the slope of the roof to be 26° 35, or 1 in 2 Walls 18 inches thick*

From the above it will be seen that the roof will, in all respects, except the truss, be the same as that given in Example III

As in Example III—

Make the battens	1¼ × 1½
" " common rafters	2¼ × 4¼
" " purlins	3½ × 5

Also, as in Example III, the span of the truss will be 25½ feet

(See *Plate* II)

<u>*Construction of Diagram*</u>

Make AB = 25½ feet

Bisect AB in C

Erect perpendicular CD = ¼ AB

Join AD and BD and bisect them in E and F

Draw EG and FH perpendicular to AD and BD

Make EG and FH each = $\frac{1}{10}$ AB (or nearly so) [= (say) 2½ feet]

Join AG, GD, BH, HD, and GH

Then —

AD and BD are *principal rafters*

EG and FH are *struts*

AG, GD, BH, HD, and GH are *tie bars*

Let W = the entire weight of the half truss with its load

It will be sufficiently accurate for the purposes of this calculation to assume that W is equally distributed along the principal rafter, and therefore that $\frac{W}{4}$ is borne at D, $\frac{W}{2}$ at E, and $\frac{W}{4}$ at A. Also as W is partly made up of allowance for work people, this will give a result somewhat in excess of the true one and thus in estimating W, the weight of the framing and timbering may be safely neglected, a great saving in trouble.

From Example III, W = 5,090 lbs.

Diagram of Forces.

Construct a diagram of forces as follows (*see Fig. 2, Plate II*) :—

Draw a line parallel to R (*Fig. 1*), and on it, on any convenient scale, in this case 2,000 lbs. = 1 inch, set off W = 5,090 lbs.

First take the forces at A. From one end of R, set off $\frac{W}{4}$ = 1272 lbs. From the end of this draw A_1 parallel to AE and from the other end of R draw C_1 parallel to AG. Produce A_1 and C_1 until they meet.

Secondly, take forces at E. From the point where A_1 meets R, set off *along R a length* $\frac{W}{2}$ = 2,545 *lbs.*, from this point, and from the other extremity of A_1 draw A_2 and A_3 respectively parallel to ED and GE. Produce them until they meet.

Thirdly, take forces at G. From the upper extremities of B and A_4 draw C_3 and C_4 parallel to GH and IK, respectively, produce them until they meet.

The diagram is now complete. The length of each line in the diagram measured off on the scale will give the amount of stress on the part of the truss which it represents.

By measuring off these lines, it is found that the amount of stress in

A_1 = 11,400 lbs. compression
A_2 = 10,300 ,, ,,
A_3 = 2,300 ,, ,,
C_1 = 10,350 tension
C_2 = 4,150 ,, ,,
C_3 = 6,150 ,, ,,

Principal Rafter

Assume a T—section $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$

Here length of principal rafter = $7.118 \times 12 = 86$ inches and greatest compression = A_1 = 11,400 lbs. = 5.09 tons

Then K (Radius of Gyration) = .717 (Table IX) and $\frac{l}{K} = \frac{86}{.717} = 120$, which for steel with one end fixed and the other rounded corresponds to a stress intensity of 2.65 tons per sq. in. (Table XII). The section has to bear $\frac{5.09}{\text{area}} = \frac{5.09}{2.5} = 2$ tons per square inch and will therefore do.

Make Principal Rafters $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ T—steel

Strut

The strut is to be of two parallel flat steel bars connected at intervals by distance pieces —Length of strut = 2 5 × 12 = 30 inches Compression on strut X_3 = 2,300 lbs = 1 03 tons From Table XII since $n = 3$ for this cross section $\frac{l}{K} = 3\frac{l}{b}$, and assuming one dimension as 1", $\frac{l}{K}$ = 3 × $\frac{30}{1}$ = 90, which corresponds to a safe stress per square inch for ends rounded of 2 77 tons The section has actually to bear 1 03 tons Hence the section of each bar might be $\frac{1\ 03}{2}$ – 2 77 = 19 square inch

Make each bar 2" × ½" to allow for the diameter of the bolt

To find the number of distance pieces required in the total length of 30", the intensity of stress in each bar will be $\frac{1\ 03}{2}$ – (2 × ½) = 1 03 tons per square inch From Table XII this intensity of stress corresponds to a ratio of 170 for ends rounded

* Hence since $n = 3\ 5$ for a rectangular cross section, the maximum safe distance between the distance pieces = ½ × $\frac{170}{3\ 5}$ = 12 1 As the length of the strut is 30, it may be divided into 3 parts, each 10 long Two distance pieces are therefore required

Tie bar M_2 or C_1.

Tension on tie-bar C_1 = 10,350 lbs

Formula IV,—$P = S \times t$

Here $t = 14000$ (Table IV),

$$S = \frac{10350}{14000} = 74 \text{ square inch}$$

Make bar $3\frac{3}{4}' \times \frac{1}{4}$ to allow for $\frac{3}{4}$ rivets

Tie bar GD or C_2

Tension on tie bar $C_2 = 4{,}450$ lbs

As before $S = \frac{4450}{14000} = 32$ square inch

Make bar $2\frac{1}{4} \times \frac{1}{4}$ to allow for $\frac{3}{4}$ rivets

Tie-bar GH or C_3

Tension on tie bar $C_3 = 6{,}150$ lbs

As before $S = \frac{6150}{14000} = 44$ square inch

Make bar $2\frac{1}{2} \times \frac{1}{4}$ to allow for $\frac{3}{4}$ rivets

Rivets

To find the number of rivets at each end of each member, using $\frac{3}{4}$ rivets and $\frac{1}{4}$ gusset plates

For single shear, $P = n \times \pi \times \frac{d^2}{4} \times 5$ tons (Formula XI)

$$= n \times \pi \times \frac{(\frac{3}{4})^2}{4} \times 5$$

$$n = 4 P$$

For bearing, $P = n \times d \times t \times 8$ (Formula XI)

$$= n \times \frac{3}{4} \times \frac{1}{4} \times 8$$

$$n = 6 P$$

Therefore only bearing values need be considered

For principal rafters, $n = 6 \times 5\ 09 = 3$ rivets

For struts, $n = 6 \times 1\ 03 = 1$ rivet

" tie-bar C_1, $n = 6 \times 4\ 6 = 3$ rivets

" " C_2, $n = 6 \times 2\ 00 = 2$ "

" " C_3, $n = 6 \times 2\ 7 = 2$ "

Abstract of Scantlings

Battens	... $1\frac{1}{4}'' \times 1\frac{1}{4}''$.
Common rafters	... $2\frac{1}{4}' \times 4\frac{1}{4}''$
Purlins	... $3\frac{1}{2}' \times 5''$
Principal rafters	... $3\frac{1}{2}' \times 3\frac{1}{2}' \times \frac{3}{8}'$ T-steel.
Struts	... 2 bars each $2'' \times \frac{1}{4}''$
Tie bars, AG.	. $3\frac{3}{4}' \times \frac{1}{4}''$
" GD	... $2\frac{1}{4}'' \times \frac{1}{4}''$
" GH	. $2\frac{1}{2}'' \times \frac{1}{4}''$

Example VI (*Plate* III)

Steel Truss for a Roof of 32 feet span

A roof is to be constructed with a Steel Truss of the form described in the "Construction of Diagram" below The clear span is 32 feet The trusses are to be 6¾ feet apart, and the common rafters 2¼ feet apart, from centre to centre The purlins, common rafters, and battens to be of sal wood Roof covering, double Allahabad tiling Slope of roof 26° 35, or 1 in 2 Walls 18 inches thick The principal rafters to be of ⊤ rolled steel, the struts of angle-steel, and all the ties of flat bar steel It is assumed in this Example that both ends of the steel trusses will be "fixed"

Then, the clear span of the truss will be 33½ feet (*See Plate* III)

<u>*Construction of Diagram*</u>

Make AB = 33½ feet
Bisect AB in C
Erect perpendicular CD = ½ AB
Join AD and BD, and trisect them in E, F, and G, H
Draw FK and HM perpendicular to AD and BD
Make FK and HM each = $\frac{1}{7 \cdot 5}$ of AB (or nearly so) [= (say) 4½ feet]
Join AK, KD, BM, MD and KM
Draw EJ and GL perpendicular to AD and BD, and meeting AK and BM in J and L
Join JF and LH

Then—

AD and BD are *principal rafters*
EJ, FK, MH, and LG are *struts*
AJ, JF, JK, KD, BL, LH, LM, MD and KM are *tie bars*

<u>*Battens*</u>

Weight of double Allahabad tiling reduced to normal } = 30lbs (Table III)

Wind pressure normal to a roof sloping $\frac{1}{2}$, } = 25 lbs (page 96)

Total = 55 lbs. per s ft

$W = 1 \times 2\frac{1}{4} \times 55 = 124$ lbs

$L = 2\ 25$ feet

Deflection—See Formula III

For sál, $bd^3 = \frac{WL^2}{330} = \frac{124 \times 2\ 25^2}{330}$

$= 1\ 9$

From Table VII, it is seen that

$b = 1''$, $d = 1\frac{1}{4}''$ will do

* *Make battens* $1'' \times 1\frac{1}{4}''$

log 2 25	= 0 35218
	[illegible]
	0 70436
log 124	= 2·09342
	2 79778
log 330	= 2·51851
log 1·9	= 0 27927

Common Rafters

$W = 55 \times 2\frac{1}{4} \times 6\ 1 = 755$ lbs.

Deflection—Formula III —

For sal $bd^3 = \frac{WL^2}{330}$

$= \frac{755 \times 6\ 1^2}{330} = 85\ 1$

See Table VII, and

* *Make common rafters* $2'' \times 3\frac{1}{2}''$

log 6 1	= 0·78532
	2
	1 57064
log 755	= 2 87794
	4 44858
log 330	= 2 51851
log 85 1	= 1·93007

Purlins

$W = 55 \times 6\ 1 \times 6\ 75 = 2{,}265$ lbs.

Deflection—Formula III —

For sál, $bd^3 = \frac{WL^2}{330}$

$= \frac{2265 \times 6\ 75^2}{330} = 312$

See Table VII, and

* *Make purlins* $3'' \times 4\frac{3}{4}''$

log 6 75	= 0·82930
	2
	1·65860
log 2265	= 3 35506
	5 01366
log 330	= 2 51851
log 312	= 2·49515

The remarks made in Example V, regarding W apply equally in this case, $\frac{W}{6}$ is borne at A, $\frac{W}{3}$ at E and F, and $\frac{W}{6}$ at D

Diagrams of Forces

I —Stresses due to permanent load.

Weight of double Allahabad tiling = 34 lbs. (Table III)

$W = 34 \times 18\ 6 \times 6\ 75 = 4{,}270$ lbs

* NOTE.—In this case calculations should be made using formula for Permanent Load and sections required are —Battens 1¼" × 1¼", Common Rafters 2" × [illegible], Purlins 3" × 5

Construct a diagram of forces as shown in *Fig* 2, *Plate* III, as follows:—
Set off R = W = 4,270 lbs, on a line parallel to R on a scale of 4,000 lbs to the inch Divide this line into four parts $\frac{W}{6}$, $\frac{W}{3}$, $\frac{W}{3}$, $\frac{W}{6}$.

First, take forces at A, *Fig* 1 —

From upper extremity of $\frac{W}{6}$ draw A_1 parallel to AE, and from upper extremity of R draw C_1 parallel to AJ, and produce these lines until they meet

Secondly, take forces at E, *Fig* 1 —

From the extremities of A_1 and $\frac{W}{3}$ draw A_4 and A_2 respectively parallel to EJ and EF, and produce these lines till they meet

Thirdly, take the forces at J —

From extremity of A_4 draw C_4 parallel to FJ The line between the point where C_4 cuts C_1 and extremity of $\frac{W}{6}$ represents C_2

Fourthly, take the forces at F:—

From the junction of C_2 and C_4 draw A_5 parallel to KF, and from extremity of $\frac{W}{3}$ draw A_3 parallel to FD Produce them till they meet

Fifthly, take the forces at K —

From the point of junction of A_3 A_5 and from the upper extremity of $\frac{W}{6}$ draw C_5 and C_3 respectively parallel to DK and KM, and produce them until they meet

The diagram of stresses is now complete The length of each line on the diagram measured off on the scale will give the amount of stress on the part of the truss, which it represents

By measuring off these lines, it is found that the amount of stress in

A_1	= 10,550 lbs	compression
A_2	= 10,000 ,,	,,
A_3	= 7,500 ,,	,,
A_4	= 1,300 ,,	,,
A_5	= 1,950 ,,	,,
C_1	= 9,500 ,,	tension
C_2	= 7,650 ,,	,,
C_3	= 5,300 ,,	,,
C_4	= 1,900 ,,	,,
C_5	= 3 000 ,,	,,

These values are now filled in column 2 of Table on page 152

Compressions are shown with + sign
Tensions ,, ,, — sign

II—Stresses due to Wind Pressure

Both ends of truss are assumed to be fixed

(a) Wind on left. Reactions parallel to Wind Pressure

Wind Pressure normal to roof sloping ½ = 25 lbs. (page 96)

W = 25 × 18.6 × 6 75 = 3,138 lbs = load on half truss. It may be assumed $\frac{W}{6}$ is borne at A, $\frac{W}{3}$ at E and F and $\frac{W}{6}$ at D, vide Fig 3, Plate III

To find the Reaction at B, take moments about A

Then $R_B \times AX = \frac{W}{3} \times AE + \frac{W}{3} \times AF + \frac{W}{6} \times AD$

$R_B = \frac{1046 \times 6.24 + 1046 \times 12.48 + 523 \times 18.72}{30}$

$= 979$ lbs

Then $R_A = W - 979 = 3138 - 979$.

$= 2159$ lbs

Construct a diagram of forces as shown in fig 4, Plate III, and enter the value of the stresses as found in column 3 of Table on page 152

(*b*) Wind on right Reactions parallel to Wind Pressure

This is exactly opposite to case (*a*) and the values of the stresses may be deduced from those there obtained Thus the stress in A_1 in the present case will be equal to the stress in A_8 case (*a*), and so on The stresses are entered in column 4 of the Table

Tabulation of stresses

We have thus obtained the stresses in the various members of the roof under the permanent load and Wind Pressure, and the maximum stress to which each member of the truss is subject, is given in column 5 This is found by adding the stress due to the permanent load, column 2, to the maximum of the stresses due to the Wind Pressure in cases (*a*) and (*b*) In the last column the stresses to be used in calculating the scantlings are given, for though the maximum stress to be borne by corresponding members on either sides of the roof is not quite the same, and the stress in the principal rafter

C_3					
C_4	− 1 000				
C_5	− 3 000	[illegible]	− 220		
A_6	+ 7 500	−1 995	+3 045	+10 545	[illegible]
A_7	+10 000	+2,400	+4 400	+11 400	+15 010
A_8	+10 500	+2 400	+4 400	+15 010	+15 010
A_9	+ 1 050	+2 400	+1 570	+ 3 520	+ 3 520
A_{10}	+ 1 500		+1 016	+ 2,310	+ 2 346
C_6	− 3 000	− 220	−1 995	− 4 995	− 4 995
C_7	− 1 900		−1,515	− 3 415	− 3,415
C_8	− 7 650	−1,710	−3,215	−10 895	−10 895
C_9	− 9 600	−1,710	−4 735	−14 255	−14,255

Principal Rafter.

Assume a T section $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$. Here length $= 6{\cdot}24 \times 12 = 74{\cdot}8$ inches. And greatest compression A_8

$= 15{,}010$ lbs $= 6{\cdot}7$ tons.

Sectional area $= 2{\cdot}55$ square inches

Then K (Radius of Gyration) $= {\cdot}717$

(Table IX) and $\frac{l}{k} = \frac{74{\cdot}8}{{\cdot}717} = 104$

which for steel with one end fixed and the other rounded, corresponds to a stress intensity of 3·08 tons per

square inch (Table XII) The section has to bear $\frac{67}{\text{area}} = \frac{67}{25} = 2\ 8$ tons and will therefore do

Make principal rafters $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$

Strut A_4

Assume an ∟ section $1\frac{1}{2} \times 1\frac{1}{2} \times 125$

Length of strut = $2' \times 12 = 24$ inches

Compression on A_4 = 2,346 lbs
= 1 05 tons

Sectional area = 361 square inch

Then k = 293 (Table X) and $\frac{l}{K} = \frac{24}{293}$ = 82 which for steel with both ends rounded corresponds to stress intensity of 3 07 tons per square inch (Table XII) The section has to bear $\frac{1\ 05}{\text{area}} = \frac{1\ 05}{361} = 2\ 9$ tons which will therefore do

Make strut A_4, $1\frac{1}{2} \times 1\frac{1}{2} \times 125$

Strut A_5

Assume an ∟ section $2\frac{1}{2} \times 2\frac{1}{2}'' \times \frac{1}{4}''$

Length of strut = $4\frac{1}{2} \times 12$
= 54 inches

Sectional area = 1 187 square inches

Compression on Strut A_5 = 3,520 lbs
= 1 57 tons

Then k = 485 (Table X) and $\frac{l}{K} = \frac{54}{485}$ = 112 which for steel corresponds to a stress intensity of 1 95 tons per square inch (Table XII) The section has to bear $\frac{1\ 57}{1\ 187} = 1\ 32$ and will therefore do

Make strut A_5, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}''$

x

Tie bar C_1

From Formula IV, $P = S \times t$

Here $P = 14{,}255$

$t = 14000$ (Table IV)

Then $S = \frac{14255}{14000} = 1.02$ square inches

Make tie-bar $3\frac{1}{2}'' \times \frac{3}{8}''$ to allow for $\frac{3}{4}''$ rivets

---

Tie bar C_2

As before $S = \frac{10895}{14000}$

$= .78$ square inch

Make tie bar $2\frac{7}{8}'' \times \frac{3}{8}''$

Tie bar C_3

As before $S = \frac{6900}{14000}$

$= .5$ square inch

Make tie bar $2\frac{1}{4}'' \times \frac{3}{8}''$

Tie bar C_4

As before $S = \frac{3415}{14000}$

$= .244$ square inch

Make tie-bar $2\frac{1}{4}'' \times \frac{1}{4}''$

Tie bar C_5

As before $S = \frac{4970}{14000}$

$= .36$ square inch

Make tie bar $2\frac{1}{4}'' \times \frac{1}{4}''$

Calculations for number of rivets required should also be made as on page 145

Abstract of Scantlings

Make —

Principal rafters, $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ T-steel

Strut LJ, $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times .125''$ L „

„ IK, $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{1}{4}''$ „ „

Tie-bars	C_1	=	$3\frac{1}{2}' \times \frac{3}{8}'$	flat	steel
"	C_2	=	2[illegible]$' \times \frac{3}{8}''$	"	"
"	C_3	=	$2\frac{1}{4}' \times \frac{3}{8}'$	"	"
"	C_4	=	$2\frac{1}{4} \times \frac{1}{4}'$	"	"
"	C_5	=	$2\frac{1}{4} \times \frac{1}{4}'$	"	"

Note.—For an Example of calculations for a truss with the load distributed on the Principal Rafters see Principles of Structural Design by Lt Col Scott Moncrieff, R E, Part I, pages 277 to 280

EXAMPLE VII (*Plate IV*)

STEEL TRUSS FOR A ROOF OF OVER 60 FEET SPAN.

A roof with a Steel Truss of the form given in the diagram is to be constructed over a shed, with a clear internal span of 72 feet, the walls being 3 feet thick the intervals between the trusses being 6 feet from centre to centre The trusses will have one end fixed and the other free to move, so as to allow for expansion or contraction The principal rafters to be of ⊤ *steel, the struts of* ∟*-steel, and the tie bars of flat steel The battens, common rafters and purlins, to be of sál wood, the battens being at 1 foot intervals, and the common rafters at 2 feet intervals, from centre to centre The slope of the roof to be 26° 35′ or 1 in 2, and the roof covering to be single Allahabad tiling*

The clear span of the truss will be $72 + 2(\frac{1}{2} \times 3) = 75$ *feet*

(*See Plate IV, Fig 1*)

Construction of Diagram

Make AB = 75 feet

Bisect AB in L

Erect perpendicular LC = $\frac{1}{4}$ AB

Join AC, CB and divide them into four equal parts, in D, E, F, and M, N, R

Drop perpendiculars FH and NK each = $\frac{1}{12}$ × AB (or nearly so) = (say 6¼ feet)

Join AH, HC, BK, KC drop perpendiculars DG, FJ, RQ and MP, and join GE, EJ, QN and NP

Draw HK parallel to AB.

Then in the half truss —

AC = the *principal rafter*

DG, EH, and FJ are *struts*,

AG, GE, EJ, JC, GH, HJ and HK are *tie bars*

Battens

Weight per square foot of single Allahabad tiling reduced to normal, roof sloping ½ (Table III) = 15 lbs

Wind pressure normal on a roof sloping $\frac{1}{2}$, page 96 (*c*) = 35 lbs

Total = 50 „

Then W = 1 × 2 × 50 = 100

Deflection—Formula III—

For sál $bd^3 = \frac{WL^2}{330} = \frac{100 \times 2^2}{330} = 1.21$

See Table VII and

Make battens 1" × 1¼"

Common Rafters

log 10.5	= 1.02118
	2
	2.04236
log 1050	= 3.02118
	5.06354
log 330	= 2.51851
log 350	= 2.54503

Length of rafter unsupported = 10½ feet

Then W = 50 × 2 × 10½ = 1,050 lbs

Deflection—Formula III—

For sál $bd^3 = \frac{WL^2}{330} = \frac{1050 \times 10.5^2}{330}$

$= 350$

See Table VII and

Make common rafters 2½" × 5¼

Purlins

log 6	= 0.77815
	2
	1.55630
log 3150	= 3.49831
	5.05461
log 330	= 2.51851
log 343	= 2.53610

Length of purlin = 6 feet

Then W = 50 × 10½ × 6 = 3,150 lbs

Deflection—Formula III—

For sál $bd^3 = \frac{WL^2}{330}$

$= \frac{3150 \times 6^2}{330} = 343$

See Table VII and

Make purlins 4½" × 4½

Truss Diagram

The procedure followed in Example VI of drawing separate diagrams for the Permanent Load and Wind Pressure and adding the resulting stresses may also be adopted in this case but another and quicker method by which the stresses may be obtained from a combined load and wind diagram will be given for this Example

Permanent Load

In considering the permanent weight on one side of the truss, it will not be desirable in this case to neglect the weight of the truss itself, as it is of considerable size. Then W may be taken to be made up as follows —

(i) Single Allahabad Tiling, 17 lbs per square foot (Table III)

(ii) Weight of half truss

Now weight of truss in lbs per sq foot of building space covered = ·08 × span in feet (Table I)

And ·08 × span = ·08 × 72 = 5·76 lbs

Then weight of half truss = 5·76 × $37\frac{1}{2}$ × 6 = 1,296 lbs

Then for permanent load W = 42 × 6 × 17 + 1,296 = 5,580 lbs

Wind Pressure.

$\left.\begin{array}{l}\text{Wind pressure}\\ \text{normal to roof}\\ \text{sloping } \frac{1}{2}\end{array}\right\} = 35\text{lbs}$ (page 96)

$W_1 = 42 \times 6 \times 35 = 8,800$ nearly

These weights may be considered as uniformly distributed along the principal rafter, or that

$\frac{W}{8} + \frac{W_1}{8}$ are borne at A

$\frac{W}{4} + \frac{W_1}{4}$ " " " D, E, and F

$\frac{W}{8} + \frac{W_1}{8}$ " " " C

Diagrams of Forces

Assume the end of the truss at B to be free to move, and the wind acting on the side A C Then the reaction at B will be vertical

Construct a diagram of forces as shown on *Fig* 2, *Plate* IV, as follows —

On any convenient scale, in this case 3,000lbs = 1," draw a line Aa parallel to the Wind Pressure acting at A (*Fig* 1) and on it set off a distance = 1,100 lbs From a draw aD parallel to the permanent load acting at A (*Fig* 1) and = 697 lbs Join AD Then A D will represent the direction and magnitude of the resultant of the permanent load and wind pressure acting at A Next draw Dd, and dE parallel to the forces acting at D (*Fig* 1) and join DE, which will represent the resultant force at D Similarly obtain the resultants of the forces acting at E, F, and C, and complete the line A CMZ The vertical lengths MN, NR, RB, BZ represent the permanent loads at M, N, R and B (*Fig* 1)

To find the reactions at A and B take any point O *Fig* 2 and complete the polar diagram by joining OD, OE, OF, OC OM, ON, OR and OB

Next draw the resultant forces through the points A, D, E, F, C, M, N, R (*Fig* 1) parallel to AD, DE, EF, etc, on *Fig* 2 Then from any point a_1 (*Fig* 1) on the resultant through A draw a_1 d_1 parallel to O D *Fig* 2, d_1 e_1 parallel to O E, and so on, completing the funicular polygon a_1 d_1 e_1 f_1 c_1 m_1 n_1 r_1 b_1. Join a_1 b_1 and from O in *Fig* 2 draw OX

parallel to a_1 b_1 meeting the vertical line through ZM produced in X. Then ZX measured to the same scale as before (3,000 lbs = 1") equals the reaction at B and XA denotes the direction and magnitude of the reaction at A.—

To find the stresses on the different members of the truss—

1st.—Take forces at A. From the extremities of the reaction at A and AD draw A1 and C_1 respectively parallel to AD, and AG (*Fig.* 1) and produce these lines till they meet.

2nd.—Take forces at D. From extremities of A_1 and DE draw A_2 and A_3 respectively parallel to GD and DE and produce them until they meet.

3rd.—Take forces at G. From junction of A_2 and A_3 draw C_2 parallel to GL and produce it until it meets C_1. The portion of C_1 lying between this point and extremity of XA represents C_2.

4th.—An inspection of the forces at L and H shows that as at each of these points the stresses in 3 of the bars are unknown, the stresses in L and H are indeterminate, and the correct way would be to determine the stress C_3 by the method of sections. Having C_3 we can find A_4 and the whole of the stress diagram.

easily follows As, however, in this case equal loads are acting on the points D, E and F, the compression on FJ (A^7) is equal to that on DG, (A_2), and further it follows from this that tension on EJ, (C_7), is equal to the tension on FG, (C_6) Then take forces at E From extremity of EF (*Fig* 2) draw A_3 parallel to EF, and produce A_5 to meet it From this point, and extremity of C_6 respectively, draw C_7 and A parallel to JE and FH, and produce these lines till they meet

5th —Take forces at H From junction of C_7 and A_6 and extremity of AN draw C_4 and C_3 respectively, parallel to JH and HK, and produce them until they meet

6th —Take forces at F From extremities of FC and A_3 draw A_4 and A_7 parallel to FC and FJ, and produce them until they meet

7th —Take forces at J Produce C_4 till it meets A_4, C_4 thus produced represents C_5

8th —Take forces at C From the extremities of C_5 and CM draw C_{10} and A_8 respectively parallel to CP and CM and produce them until they meet

9th —Take force at M From the extremities of A_8 and MN draw

A_{12} and A_9 parallel to MP and MN and produce them until they meet

The remainder of the diagram for the right side of the truss can now be completed in the same way as for the left side

In this example the stresses on the half of the truss on which the wind does not act have been worked out, and shown on the diagram, in practice it will be unnecessary to do this

The lengths of each line can then be measured off on the scale and the stresses determined thus —

$A_1 = 31{,}600$	lbs	compression
$A_2 = 31{,}000$	"	"
$A_3 = 30{,}400$	"	"
$A = 29{,}800$	"	"
$A_5 = A_7 = 3{,}400$	"	"
$A_6 = 6{,}800$	"	"
$A_8 = 22{,}200$	"	"
$A_9 = 22{,}800$	"	"
$A_{10} = 23{,}400$	"	"
$A_{11} = 24{,}000$	"	"
$A_{12} = A_{14} = 1{,}250$	"	"
$A_{13} = 2{,}500$	"	"
$C_1 = 32\ 200$	"	tension
$C_2 = 26{,}600$	"	"
$C_3 = 12{,}900$	"	"
$C_4 = 14{,}500$	"	"
$C_5 = 20{,}100$	"	"
$C_6 = C_7 = 5{,}600$	"	"
$C_8 = C_9 = 2{,}050$	"	"
$C_{10} = 9{,}700$	"	"
$C_{11} = 7{,}650$	"	"

C =19,750 lbs tension

C_{13}=21,800 " "

The stresses to be used in calculating the scantlings will however be the same for the corresponding members on either side of the truss

---

Principal Rafter

Greatest compression is that on A_1 = 31,600 lbs =14 1 tons

Here length=10 5 × 12 = 126 inches Assume a T section 6 × 4 × $\frac{1}{2}$", whose area=4 771 square inches

Then $\frac{l}{K}=\frac{126}{1\ 128}$ (Table IX)=111 which for steel with one end fixed and the other rounded corresponds to a stress intensity of 2 88 tons per square inch (Table XII) The section has to bear $\frac{14\ 1}{4\ 771}$ = 2 96 tons per square inch and is not therefore sufficiently strong It will be found that a section 6 × 4" × $\frac{5}{8}$ will do

Make principal rafters 6 × 4 × $\frac{5}{8}$ *

Struts $A_5 = A_7$

Compression on each = 3,400 lbs = 1 52 tons

Length = 3 × 12 = 36 inches Assume an L section 2 × 2 × 175 Sectional area is 670 square inch Then $\frac{l}{K}$ = $\frac{36}{388}$ (Table X)=93 which for steel, ends rounded, corresponds to a stress intensity of 2 56 tons per square inch (Table XII) The section has to bear $\frac{1\ 52}{670}$ = 2 3 tons per square inch and will therefore do

Make struts A_5 and A_7 2 × 2 × 175"

---

* NOTE — It would probably be cheaper to use two angles back to back for the principal rafter

Strut A_6

Compression on strut = 6,800 lbs = 3.04 tons

Length = 6.5 × 12 = 78 inches

Assume an ∟ section $3\frac{1}{2} \times 3\frac{1}{2} \times 3$

Sectional area is 2.011 square inches

Then $\frac{l}{k} = \frac{78}{.684}$ (Table X) = 114 which for steel, ends rounded, corresponds to a stress intensity of 1.95 tons per square inch (Table XII)

The section has to bear $\frac{3.04}{2.011} = 1.5$ tons and is strong enough

Make strut A_6 $3\frac{1}{2} \times 3\frac{1}{2} \times 3$

Tie bar C_1

From Formula IV, $P = S \times t$

Here $P = 32,200$ lbs and

$t = 14,000$ lbs

Then $S = \frac{32200}{14000} = 2.3$ square inches

Make tie bar $C_1 = 5\frac{3}{8} \times \frac{1}{2}$ to allow for $\frac{3}{4}$ rivets

---

Tie bar C_2

Here $P = 26,600$ lbs

and $S = \frac{26600}{14000} = 1.9$ square inches

Make tie bar $C_2 = 4\frac{1}{2}'' \times \frac{1}{2}''$ to allow for $\frac{3}{4}''$ rivets

---

Tie bar C_3

Here $P = 12,900$ lbs

and $S = \frac{12900}{14000} = .92$ square inch

Make tie-bar $C_3 = 2\frac{1}{2} \times \frac{1}{2}''$ to allow for $\frac{3}{4}'$ rivets

---

Tie bar C_4

Here $P = 14,500$ lbs

and $S = \frac{14500}{14000} = 1.04$ square inch

Make tie bar $C_4 = 2\frac{7}{8}'' \times \frac{1}{2}''$ to allow for $\frac{3}{4}$ rivets

Tie bar C

Here P = 20,100 lbs

and $S = \frac{20100}{14000} = 1\ 43$ square inches

Make tie-bar $C_5 = 3\frac{5}{8} \times \frac{1}{2}$ *to allow for* $\frac{3}{4}$ *rivets*

Tie bars C_6 and C_7

Here P = 5,600 lbs

and $S = \frac{5600}{14000} = 4$ square inch

Make tie bars C_6 and $C_7 = 2\frac{1}{2} \times \frac{1}{4}$ to allow for $\frac{3}{4}$ rivets

Rivets

To find the number of rivets at each end of each member, using $\frac{3}{4}$ rivets and $\frac{1}{2}$ gusset plates

For single shear, $P = n \times \pi \times \frac{(\frac{3}{4})^2}{4} \times 5$ or

$n = 45P$,

For bearing $P = n \times \frac{3}{4} \times \frac{1}{2} \times 8$ or

$n = 3\ P$

Therefore only shearing values need be considered

For principals $n = 45 \times 14\ 1 = 7$

„ struts A_4 A_7 $n = 45 \times 1\ 5 = 1$

„ „ A_6 $n = 45 \times 3\ 04 = 2$

„ tie bar C_1 $n = 45 \times 14\ 4 = 7$

„ „ C_2 $n = 45 \times 11\ 9 = 6$

„ „ C_3 $n = 45 \times 5\ 8 = 3$

„ „ C_4 $n = 45 \times 6\ 4 = 3$

„ „ C_5 $n = 45 \times 8\ 9 = 4$

„ „ C_6 C_7 $n = 45 \times 2\ 5 = 2$

In the cases where more than 3 rivets are necessary, they should be grouped round the centre fibre of the bars, one rivet being in the first row as in the calculations for sizes of the bars it has been assumed that the bar is weakened only by one rivet section

Abstract of Scantlings

Make—

Principal rafters,	[illegible] × 4 × $\frac{3}{8}$	⊤ steel
Struts DG & FJ,	2 × 2 × 175	⌊ steel
„ EH,	$3\frac{1}{2} \times 3\frac{1}{2} \times 3''$	„
Tie-bar AG,	$5\frac{3}{8}'' \times \frac{1}{2}''$	flat steel
„ GH,	$4\frac{1}{2}'' \times \frac{1}{2}$	„ „
„ HK,	$2\frac{1}{2} \times \frac{1}{2}''$	„ „
„ HJ,	$2\frac{7}{8}'' \times \frac{1}{2}$	„ „
„ JC,	$3\frac{5}{8} \times \frac{1}{2}$	„ „
„ GE EJ,	$2\frac{1}{2} \times \frac{1}{4}$	„ „

EXAMPLE VIII (*Plates VII and VIII*)
VERANDAH ROOF

A roof has to be constructed to the verandah of a family quarter The principal rafters are 7' 6" apart and the roof covering is single Allahabad tiling, the wood used is deodar The width of the verandah is 12 feet Common rafters 2' [illegible] apart Width of end verandah 10 feet Slope of 12 foot verandah roof, 1 in [illegible]

Spans of verandah roofs = 13' 6" and 11' 6" *respectively*
Projection at eaves = 2 feet from centre of bressumer, in 12 foot verandah

A. 12 FOOT VERANDAH
(*See Plate VII, Fig 1*)

Construction of Diagram

Make AB = 12' + [illegible] + 9" + 2' = 15' 6"

Draw BC at right angles to AB and = ½ AB

Join AC

Make AD = 2 feet, and draw perpendicular DE

Draw horizontal line EF, and bisect it in G

Erect perpendicular GH, and join HF

Then—

EH and HF are *principal rafters*

EF is the *tie-rod*

AC is *common rafter*

Battens

log 2.5	= 0.39794
	2
	0.79588
log 72	= 1.85733
	2.65321
log 250	= 2.39794
log 1.8	= 0.25527

W = 1 × 2½ × 28.5 = 72 lbs (Weight of tiling + workmen reduced to normal)

Deflection—Formula III —

For deodar $bd^3 = \frac{WL^2}{250}$

$= \frac{72 \times 2\frac{1}{2}^2}{250} = 1.8$

See Table VII and

Make battens 1½ × 1¼"

Common Rafters

log 7.5	= 0.87506
	2
	1.75012
log 535	= 2.72835
	4.47847
log 250	= 2.39794
log 120	= 2.08053

W = 2½ × 7½ × 28.5 = 535 lbs

Deflection—

$bd^3 = \frac{WL^2}{250}$

$= \frac{535 \times 7\frac{1}{2}^2}{250} = 120$

See Table VII and
Make common rafters 2 × 4

Purlins

2 log 7.5	= 1.75012
log 1603	= 3.20493
	4.95505
log 250	= 2.39794
log 360	= 2.55711

$W = 7\frac{1}{2} \times 7\frac{1}{2} \times 28.5$
$= 1,603$ lbs

Deflection—

$$bd^3 = \frac{W l^2}{250}$$
$$= \frac{1603 \times 7.5^2}{250} = 360$$

See Table VII and
Make purlins 3″ × 5″

Principal Rafters

The weight of roof covering is distributed as follows:—¼ at F, ½ at H, and ¼ at C

Now weight of single Allahabad tiling (Table III)	= 17 lbs
Allowance for work people taken as acting vertically, page 95)	= 15 lbs
Total	= 32 lbs

Then $W = 32 \times 15 \times 7\frac{1}{2} = 3,600$ lbs

Now the compression on the two principal rafters being entirely due to the weight acting at H, are necessarily equal to each other

log sin 26° 35′	= 9.65079
log 4	= 0.60206
	0.25285
log 3600	3.55630
log 2011	= 3.30345

Resolve vertically

and $2c_1 \cos JHG = \frac{W}{2}$

or $c_1 = \frac{3600}{4 \times \sin 26° 35′}$

$= 2,011$ lbs,

and $S = \frac{4P}{c}$, Formula V.

Here $c = 700$, Table IV.

and $S = \frac{4 \times 2011}{700} = \frac{8044}{700} = 11\ 5$

Make principal rafters $3'' \times 4''$

Tie rod

L cos 26° 35	= 9 95179
log 2011	= 3 30345
log 4	= 0 60206
	= 3 85730
log 3 1416	= 0 49715
log 14000	= 4 14612
	4 64327
Subtract	2)$\bar{1}$ 21403
log 404	$\bar{1}$ 60701

Resolve horizontally

and $T = c_1 \cos\ HFG,$

$= 2011 \cos\ 26°\ 35$

and $2r = \sqrt{\frac{4 \times 2011 \cos 26\ 35}{3\ 1416 \times 14000}}$

$= 404$

Make tie rod $\frac{1}{2}$ *diameter*

B 10 FOOT VERANDAH

(*See Plate* VII, *Fig* II)

Construction of Diagram

Make EF = 10 + 9 + 9 = 11 5

Erect perpendiculars KL and FC, KF being = 9 inches

Now the two verandahs cut the wall at the same level

Make KL = KL in *Plate* VII, *Fig* I

And the eaves terminate at the same level

Make LD = ED in *Plate* VII, *Fig* I

Draw horizontal line DA

Join EL and produce it to A and C

Bisect EC in H and join HF

Draw perpendicular HG

Then—

EH and HF are *principal rafters*

EF is *tie rod*

AC is *common rafter*

Slope of Roof

Now slope of roof $= \sin^{-1} \frac{CF}{CE}$

$= \sin^{-1} \frac{6\ 8}{13\ 4}$

$= \sin^{-1}\ 5074627$

$= \sin\ 30°\ 30$

Normal Pressure

The normal pressure per square foot of single Allahabad tiling
$= 17 \cos \theta$, (Table III)
$= 17 \cos 30^\circ 30 = 14\ 7$ lbs

Normal allowance for work people
$= 15 \cos \theta$,
$= 15 \cos 30^\circ 30 = 13$ lbs
Total normal pressure $= 27\ 7$ lbs nearly

Battens

log 2 5	= 0 39794
	2
	0 79588
log 70	= 1 84510
	2 64098
log 250	= 2 39794
log 1 75	= 0 24304

$W = 1 \times 2\frac{1}{2} \times 27\ 7 = 70$ lbs
Deflection—Formula III—
For deodar $bd^3 = \frac{W L^2}{250}$
$= \frac{70 \times 2\frac{1}{2}^2}{250} = 1\ 75$
See Table VII and
Make battens $1\frac{1}{4} \times 1\frac{1}{4}$

Common Rafters

log 6 7	= 0 82607
	2
	1 65214
log 464	= 2 66652
	4 31866
log 250	= 2 39794
log 83 3	= 1 92072

$W = 2\frac{1}{2} \times 6\ 7 \times 27\ 7 = 464$ lbs
Deflection—Formula III—
For deodar $bd^3 = \frac{W L^2}{250}$
$= \frac{464 \times 6\ 7^2}{250} = 83\ 3$
See Table VII and
Make common rafters $2'' \times 3\frac{1}{2}''$.

Principal Rafters

L sin 30 30′	= 9 70546
log 4	= 0 60206
	0 30752
log 3216	= 3 50731
log 1584	= 3 19979

Taking the distribution of weight as before,
$W = 32 \times 13\frac{3}{4} \times 7\frac{1}{2} = 3{,}216$
And as before—
$c_1 = \frac{3216}{4 \times \sin 30^\circ 30'}$
$= 1{,}584$ lbs.

and $S = \frac{4P}{c}$, Formula V.

Here $c = 700$, Table IV.

and $S = \frac{4 \times 1584}{700} = \frac{6336}{700} = 9.05$

Make principal rafters 3′ × 3′.

Tie-rod.

L cos 30° 30′	= 9.93532
log 1584	= 3.19979
log 4	= 0.60206
	3.73717
log denominator	= 4.64327
	2)$\bar{1}$.09390
log 352	= $\bar{1}$.54695

As before—

$$d_1 = \sqrt{\frac{4 \times 1584 \times \cos 30^{\circ} 30'}{3.1416 \times 14000}}$$

$= .352$

Make tie rod $\frac{3}{8}$ *diameter*

C. Hip Rafter

(*See Plate* VIII., *Fig* iii.)

Construction of Diagram.

Draw a plan of the angle of the verandah

Dotted lines—Centre lines of wall

Firm lines—Principal rafters

Thin lines—Common rafters and purlins.

Chain dotted lines—Plans of lines turned into plane *of paper*.

Weight on Hip Truss

To turn the triangle AOB into the plane of the paper

Make BO_1 = EC in *Fig* i, and join AO_1

Then AO_1 is the length of slope of the hip

Let W_1 = vertical weight on triangle AO_1B,

$= \frac{1}{2} AB \times BO_1 \times 32$ lbs

$= \frac{1}{2} \times 11\frac{1}{2} \times 15 \times 32 = 2{,}760$ lbs

and of this, half is borne by the hip rafter.

Similarly to turn the triangle AOE into the plane of the paper

Make $EO_{11} = EC$ in *Fig* ii

Join AO_{11}

Let W_2 = vertical weight on triangle $AO_{11}E$,

$= \frac{1}{2} \times AE \times EO_{11} \times 32$ lbs

$= \frac{1}{2} \times 13\frac{1}{2} \times 13\frac{1}{2} \times 32 = 2,916$ lbs,

and of this, again, half is borne by the hip rafter

(*See Plate* VIII *Fig* iv)

Construction of Elevation of Hip Truss

Make $AB = AO$, *Fig* iii

Erect perpendicular BE

With centre A and radius $= AO_1$ or AO_{11} (*Fig* iii), describe a circle cutting BE in E

Join AE

Bisect AE in F, and join FB

Then—

AF and FB are *principal rafters*

AB is *tie rod*

W = Total weight on Hip Truss

$W = \frac{1}{2}(W_1 + W_2)$

$= \frac{2760 + 2916}{2} = \frac{5676}{2}$

$= 2,838$ lbs

Angle of inclination of Rafter

$\text{Sin } EAB = \sin^{-1}\frac{EB}{AF}$

$= \sin^{-1}\frac{6.7}{19}$

$= \sin^{-1} .3526316$

$= 20° 39'$

Principal Rafters.		
log 4	= 0 60206	
L sin 20 39	= 9 54705	
	0 14911	
log 2838	= 3 45301	
log 2013	= 3 30390	

As before—

$$c_1 = \frac{2838}{4 \times \sin 20^\circ 39}$$

= 2013 lbs

and $S = \frac{4P}{c}$, Formula V,

and here $c = 700$, Table IV.

Then $S = \frac{4 \times 2013}{700} = \frac{8052}{700} = 11\ 5$

Make principal rafters 3 × 4.

Tie rod		
L cos 20° 39	= 9 97201	
log 2013	= 3 30390	
log 4	= 0 60206	
	3 87797	
log denominator	= 4 64327	
	2) $\bar{1}$ 23470	
log 414	= $\bar{1}$ 61735	

As before—

$$2r = \sqrt{\frac{4 \times 2013 \times \cos 20^\circ 39}{3\ 1416 \times 14000}}$$

= 414

Make tie rod ½ diameter

Common Rafters and Purlins lying on Hip Truss

Make the common rafters and purlins the same as in their respective verandahs on either side of the hip truss

---

D. Coupled Rafters

These are very common in roofs of out houses, covered passages, and as planked trusses in small buildings in the Hills The roof covering rests uniformly on the rafters, either as battens or planking, and thus causes them to be under complex stress i e a direct thrust and transverse stress

---

Example VIII D

A roof, as shown on Plate XLII, has to be constructed over a Servant's quarter. The principal rafters are 3½ feet apart, and the roof covering is single Allahabad Tiling, the wood used is deodar The battens, 1 foot apart, rest direct on the principal rafters The slope of the roof is 1 in 2

Battens

log 2	= 0·30103
log 100	= 2·00000
log 3·5	2 × 0·54406
	2
	1·08812
log numerator	= 3·38915
log 3	= 0·47712
log 250	= 2·39794
	2·87506
log 3·26	= 0·51409

Principal Rafters

log 112	= 2·04921
log 2	= 0·30103
log sin 26° 35	= 9·65079
	9·95182
log 125	= 2·09739

$W = 1 \times 28{\cdot}5 \times 3\frac{1}{2} = 100$ lbs.

Deflection—Formula III, for deodar, in case of fixed beams,

$$bd^3 = \frac{2}{3} \times \frac{WL^2}{250} = \frac{2}{3} \times \frac{100 \times 3\frac{1}{2}^2}{250}$$

$$= 3{\cdot}26$$

Make battens $1\frac{1}{2}' \times 1\frac{1}{2}$ *see* Table VII.

As in Example VIII A, resolving vertically we have for *direct thrust*—

$W = 2\ c_1 \cos$ EHG and

$$W = 1 \times 32 \times 3\frac{1}{2} = 112$$

$$\text{or } c_1 = \frac{112}{2 \sin 26^\circ 35} \times 7$$

$$= 125 \times 7$$

$$= 875 \text{ lbs}$$

The principal rafters are supported by battens at 1 foot intervals, so that length is between 1 and 8 times the least sectional dimension Then Formula V, $P = S \times c$

For deodar $c = 700$ (Table IV)

$$\text{Then } S = \frac{P}{c} = \frac{875}{700} = 1{\cdot}25 \quad \ldots\ldots (i).$$

Transverse stress—For deodar

$$bd^2 = \frac{WL}{150} = \frac{28{\cdot}5 \times 3\frac{1}{2} \times 7 \times 7}{150}$$

$$= \frac{100 \times 49}{150} = 32{\cdot}67 \quad \ldots\ldots (ii)$$

Then $b = {\cdot}32$ $d = 4$ satisfies ......(i)

$b = 2{\cdot}04$ $d = 4$ „ .... (ii)

Add the two values of b and *make principal rafters* $2\frac{1}{2} \times 4$

N B —For the theory involved in the above method, *see* " Roorkee Manual of Applied Mechanics, Vol I, pages 281—287

Example IX

Hammer Beam Truss

A roof is to be constructed over the nave of a Church built in the gothic style of architecture. The width of the nave is 32 feet, the slope of the roof is to be 45°, the roof covering is to consist of 22 B. W. G. plain sheet iron laid on the Aami Tal pattern on 1½ inch teak planking, on purlins at 5½ feet central intervals, which again rest on hammer-beam trusses spaced at 9 feet central intervals. The wood work is to be teak, and the hammer beam trusses of the form shown in Plate IX, Fig 1.

<u>*Construction of Truss*</u>

See Plate IX, Fig. 1

Set off BB equal to 32 feet. Bisect it in E,′ and draw EE perpendicular to BB′. Make EE equal to $\frac{BB}{2}$, and join BE and BE.

Bisect BE and BE in D and D and join DD.

From D and D draw DC and DC perpendicular to BB cutting it in C and C′. From B and B draw BA and BA perpendicular to BB, and make BA = BA′ = DC = DC′. Draw CG and FH perpendicular to BE, and CG and FH perpendicular to BE. Join FE and draw the curved struts AC, A′C′ and CF, C′F. The truss is then complete.

In this truss BC, BC′ are horizontal ties. AC, A′C′ are struts curved for architectural effect. CF, C′F are curved stays or stiffeners to provide against irregularities of the load. The upper portion DED is a king post truss, and CG, CG′ are struts supporting the principal rafters at G, G′ where purlins come.

NOTE — *Most officers hold different views regarding the best way of calculating the stresses in a hammer beam truss The following solution has no pretension to be mathematically correct, but it is considered to be sufficiently accurate to answer all practical purposes It is doubtful if a strictly mathematical solution be possible*

Vertical or Permanent Load — *First* consider only the vertical or permanent load, which on one half the truss say = W

This acts as shown in *Fig* 1 as under, $\frac{W}{8}$ at E $\frac{W}{4}$ at H, $\frac{W}{4}$ at D, $\frac{W}{4}$ at G, and $\frac{W}{8}$ at B The reaction of the wall may be resolved vertically and horizontally The vertical component R = W, and the horizontal component T has to be determined hereafter

Now, weight of 22 B W G plain sheet iron including lappage = 1 40 lbs per square foot

$1\frac{1}{2}''$ teak planking = $\frac{52}{8}$ = 6 5 lbs per square foot Therefore weight of roof covering = 7 9 lbs per square foot

Then—

W = 7 9 × 22 5 × 9 × 1 (roof-covering)
+ $3\frac{1}{2}$ × 9 × 52 × $\frac{4 \times 6}{144}$ (purlins)
+ 16 × 9 × 2 5 (truss)
= 1600 + 273 + 360
= 2,233 lbs

Now assuming that the curved stiffeners CF, CF can be neglected, the truss may be considered to be a king post truss DLD supported by two compound struts ABDC and ABDC. The forces acting on the compound strut ABDC are (1) the reaction of the wall at A, (2) the weight of the roof resting on it, and (3) the force exerted on it by the king post truss DED acting at D. Resolving these forces vertically and horizontally, the vertical components are, R = W at A, $\frac{W}{8}$ at B, $\frac{W}{4}$ at C, $\frac{5W}{8}$ at D, the horizontal components are T at A and T = T at D. Taking moments round D,

$$T \times 16 = R \times \frac{16}{2} - \frac{W}{8} \times \frac{16}{2}$$
$$- \frac{W}{4} \times \frac{16}{4}$$

$$\text{or } T = \frac{W}{2} - \frac{W}{16} - \frac{W}{16} = \tfrac{3}{8} W$$
$$= \tfrac{3}{8} \times 2{,}233 = 837 \text{ lbs}$$

The stress diagram shown in *Fig.* 3 can now be drawn as follows:—Commencing with the forces at A draw *aa* parallel to T and on a scale of 1,200 lbs to one inch make it = 837 lbs, draw *a'd* vertical = R = 2,233 lbs, and *ae* parallel to AC cutting *ad* in *e*. Then *aa dea* is the diagram of stresses at the point A. The other diagrams are B, *e d g b e*, C, *b g e f b*, C, *a e l f a*, D, *a f e e a*, H, *a e s h a*, L, *h s h h*, I, *s h h a* and so on for the other side.

of the truss The chief points brought out by these diagrams are that there is no stress in DF and D F, and that if the curved pieces CF and C F had been introduced, the diagrams, which are complete without their assistance, would have been indeterminate at C and C

Temporary Load or Wind Pressure

The normal wind pressure on a roof sloping $\frac{1}{1}$ is, *see* page 96 39 lbs per square foot

Let W_1 = total normal wind pressure on one side of the roof

Then $\frac{W_1}{8}$ acts at B, $\frac{W_1}{4}$ at G, $\frac{W_1}{4}$ at D $\frac{W_1}{4}$ at H, and $\frac{W_1}{8}$ at E

A hammer beam truss is secured to the walls at A, B, A, B, while the parts AB and A B rest against the walls The reactions of the walls at these points are indeterminate depending on accuracy of construction, and as different assumptions regarding their mode of action give rise to very different diagrams of stresses, it is believed a mathematically accurate diagram cannot be drawn With the wind acting as shown on *Fig* 2, it is evident that most of the reaction against it will be exerted by the wall at A B, while of the part exerted by AB, that at B cannot be great, as the wall there has little holding power and it may be assumed without much risk of error that it acts at A

Now by the method of sections if the truss be cut by a plane passing through D and CF, to sustain the lower part of the truss thus cut off there is the thrust T_1 at D, and the stress of the tie CF = T acting along this bar, taking moments round D,

$R \times 3 = \frac{W_1}{8} \times 2 + \frac{W_1}{4} \times 1 + T \times 1$

or $R = \frac{W_1}{6} + \frac{T}{3}$ (1)

If the tie CF be considered omitted, then $R = \frac{W_1}{6}$, and the diagram, *Fig* 4, can be drawn for the truss, which gives a thrust on $CF = \frac{7}{6} W_1$ (*am* in diagram) This is excessive, and there is no good reason for supposing that CF will not help as a tie to relieve this strain Assume $R = \frac{W_1}{4}$, then equation (1),

$\frac{W_1}{4} = \frac{W_1}{6} + \frac{T}{3}$,

or $\frac{T}{3} = \frac{W_1}{4} - \frac{W_1}{6} = \frac{W_1}{12}$

or $T = \frac{W_1}{4} = R$,

which is found to be the case by the diagram that can now be drawn of the stresses of the truss as follows —

Now $W_1 = 22.5 \times 9 \times 39 = 7898$ lbs.

On a scale of 1,500 lbs. = 1 inch draw, *see Fig* 5, *bc* parallel to R and equal to $\frac{W_1}{4} = 1975$ lbs., from *b* and *c* draw *ba* and *ca* parallel to BA and CA respectively Then the diagram of stresses at A is *bcab*, at B, *abdea*, at G, *dfged*, at C, *fhijkf*, where *kf* equals stress on CF or T above, which equals *ac* or R as stated

above, at D *hlmnoh*, at H, *onpqo*, at E, *lrml* at F, *hlmsth*

From this diagram it is apparent that there is no stress in the principal rafter EL, *vide* diagram for E, or in any of the other parts of the truss, except FC and AC, in which there is a thrust of $\frac{3W_1}{4} = R$ which thus acts at A. This if checked by the method of sections through D will be found correct, and as it makes the tie CF bear $\frac{W_1}{4}$ in tension and the strut CF $\frac{3W_1}{4}$ in compression, it may be regarded as a satisfactory solution of the problem.

By measuring off the lengths of the different lines in the diagrams *Figs* 3 and 5 a Table of Maximum Stresses on the different parts of one-half the truss can be drawn up as follows —

Part of truss	Permanent load	Wind on left	Wind on right	Maximum stress on each part of truss
AB	$+\frac{5}{8}W$	$+\frac{1}{4}W_1\sqrt{2}$	*nil*	$+\frac{5}{8}W+\frac{1}{4}W_1\sqrt{2}=+4168$ lbs
AC	$+\frac{5}{8}W\sqrt{2}$	$-\frac{1}{4}W_1$	$+\frac{3}{4}W_1$	$+\frac{5}{8}W\sqrt{2}+\frac{3}{4}W_1=+7108$
BC	$-\frac{5}{8}W$	$\frac{1}{8}W_1\sqrt{2}$	*nil*	$-\frac{5}{8}W\ \frac{1}{8}W_1\sqrt{2}=\ 2513$
BG	$+\frac{3}{8}W\sqrt{2}$	$+\frac{3}{8}W_1$		$+\frac{3}{8}W\sqrt{2}+\frac{3}{8}W_1=+4541$
CG	$+\frac{1}{8}W\sqrt{2}$	$+\frac{1}{4}W_1$		$+\frac{1}{8}W\sqrt{2}+\frac{1}{4}W_1=+2369$
CD	$+\frac{1}{8}W$	$-\frac{1}{8}W_1\sqrt{2}$		$\frac{1}{8}W_1\sqrt{2}-\ 1396$
CE	*nil*	$-\frac{1}{4}W_1$	$+\frac{3}{4}W_1$	$+\frac{3}{4}W_1=+5923$
DF		$+\frac{3}{8}W_1\sqrt{2}$	*nil*	$+\frac{3}{8}W_1\sqrt{2}=+4168$
DH	$+\frac{3}{8}W\sqrt{2}$	$-\frac{1}{8}W_1$		$+\frac{3}{8}W\sqrt{2}=+1184$
HF	$+\frac{1}{4}W\sqrt{2}$	$-\frac{1}{8}W_1$		$+\frac{1}{4}W\sqrt{2}=+\ 789$
EF	$-\frac{1}{8}W$	$+\frac{1}{8}W_1\sqrt{2}$	$+\frac{1}{8}W_1\sqrt{2}$	$+\frac{1}{8}W_1\sqrt{2}=+1396$
DG	$+\frac{3}{8}W\sqrt{2}$	$+\frac{3}{8}W_1$	*nil*	$+\frac{3}{8}W\sqrt{2}+\frac{3}{8}W_1=+4146$
HE	$+\frac{1}{8}W\sqrt{2}$	$+\frac{1}{4}W_1$		$+\frac{1}{8}W\sqrt{2}+\frac{1}{4}W_1=+2369$

Compressions + Tensions —

To calculate dimensions of different parts of truss

Principal Rafters BD

Length unsupported laterally = BG = 5 [illegible] feet

Formula V, $S = \frac{2P}{c}$

Here P = 4541 lbs $c = 1210$ lbs

Then $S = \frac{2 \times 4541}{1210} = \frac{9082}{1210} = 7.5$

Make principal rafter 3" × 3

Curved Strut AC

Here P = 7108,

$S = \frac{2 \times 7108}{1210} = \frac{14216}{1210} = 11.75$

but as strut is curved make

S = 18, or

Make curved strut AC 3" × 6

Struts AB, DF

As before—

$S = \frac{2P}{c}$

Here P = 4189 lbs

and $S = \frac{2 \times 4189}{1210} = \frac{8378}{1210}$

$= 6.92$

Make struts AB, DF 3" × 3" *for architectural reasons*

Curved Strut CF

Here P = 5923

and $S = \frac{2 \times 5923}{1210} = \frac{11846}{1210}$

$= 9.79$

but as strut is curved make

S = 18, or

Curved strut CF 3" × 6"

Struts CG *and* HF.	Here P = 2369
	and $S = \frac{2 \times 2369}{1210} = \frac{4738}{1210}$
	$= 3.91$
	Make struts CG, FH 3″ × 3 *for architectural reasons*
Tie BC	Formula IV—
	$P = S \times t$
	Here P = 2513, t = 1210
	Then $S = \frac{2513}{1210} = 2.08$
	Make BC 3 × 3 *for architectural reasons*
Abstract of Scantlings	*Make*—

Principal rafters EB,	3	×	3
Curved struts AC,	3	×	6″
Struts AB, DF,	3	×	3
Ties BC, CD,	3	×	3
Struts CG, FH,	3	×	3
Tie EF,	3″	×	3″
Curved stays CF, CF,	3	×	6″

Calculate purlins as in previous Examples

The points A, B, A, B, must be firmly fixed to the walls by iron cramps, and the walls must be supported by buttresses at A, A, calculated to resist the maximum thrust at these points

This is made up of $ad = \frac{17}{16}$ W, *see Fig* 3, in amount and direction for permanent load, and $R = \frac{3}{4} W_1$, *Fig* 5, for temporary load. The resultant of these two forces will give amount and direction of greatest thrust on walls

NOTE.—In making calculations for a truss similar in proportion to the above, it will not be necessary to go through all these elaborate calculations. It will merely be necessary to reconstruct the table of stresses for the altered conditions of W and W_1, in each case, remembering that the proportion between each stress and the load will remain the same in each case.

The dimensions of each part of the truss can then be calculated for the stresses given in the table reconstructed as explained above.

Trussed Beams.

The following are given as two simple Examples for a guide in cases where it is necessary either to truss old beams which have unduly deflected, or where, in a new building, it is required to use a beam with a smaller scantling than will carry the load, either in order not to place the beams too close together, or in cases where it is not convenient to use beams of the full calculated scantling

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EXAMPLE X (*Plate X*)

Let AB *be the beam, with a span of* 16 *feet, the* total *distributed load being* 20,000 *lbs, for one of the reasons given above, it is required to truss the beam with a single strut of a length* = $\frac{1}{12}$*th of the span*

Length of strut = $\frac{1}{12} \times 16$ *feet* = 16 *inches*

(*See Plate X, Fig* 1)

Construction of Diagram of central lines of struts and ties

Make AB = 16 feet
Bisect AB in C
Drop perpendicular CD = 16 inches
Join AD and DB
Then—
CD is a *strut*
AD and DB are *tie rods*

Now, of the distributed load, $\frac{1}{4}$ is borne at A, 1 at C, and $\frac{1}{4}$ at B

---

c = Compression on Strut CD

The point C is in equilibrium
Resolve along CD
$c = \frac{1}{2}$ W
= 10,000 lbs
Calculate scantling by Formula V.

---

t = Tension of Tie rods AD *and* DB

Again the point D is in equilibrium.
By symmetry—
Tension on AD = tension on BD
Resolve along CD
c = [illegible] cos ADC

$\log c = \log 10000$	$= 4.00000$
$\frac{1}{2}\log 9172$	$= 1.98822$
log numerator	$= 5.98822$
$\log 32$	$= 1.50515$
$\log t = \log 30414$	$= 4.48307$

$$= 2t \times \frac{CD}{AD}$$

But $AD = \sqrt{AC^2 + CD^2}$

$$= \sqrt{144 \times 64 + 256}$$

$$= \sqrt{9172}$$

$$\therefore t = \frac{c \times \sqrt{9172}}{32}$$

$$= 30{,}414 \text{ lbs}$$

Calculate diameter, or side of square of steel tie rod by Formula IV.

---

c_1 = *Compression on Beam* AB

$\log t$	$= 4.48307$
$\log AC = \log 96$	$= 1.98227$
log numerator	$= 6.46534$
$\log AD = \frac{1}{2}\log 9172$	$- 1.98822$
$\log c_1 = \log 30000$	$= 4.47712$

Again the point A is in equilibrium

Resolve along AB

$$c_1 = t \cos CAD^\circ$$

$$= t \times \frac{AC}{AD}$$

$$= 30{,}000 \text{ lbs}$$

In addition to this however as the load is uniformly distributed there is a transverse stress on AC and CB

Weight on AC $= \frac{W}{2} = 10{,}000$ *lbs.*

Length $= 8$ feet

Transverse stress—Formula III

For sal $bd^2 = \frac{WL}{250}$

$$= \frac{10000 \times 8}{250} = 320, \text{ (i)}$$

Direct stress—Formula V—

For sal $S = \frac{P}{c} = \frac{30000}{1210}$

(NOTE.—The beam AC is supported laterally by joists at about 1 foot intervals, hence it is a short strut.)

Then $S = bd = 24.7$ (ii)

See Table VIII

Then—

$b = 4,\quad d = 9$ satisfies equation (i)

$b = 2.74, d = 9$ " " (ii)

Make beam AB $6\frac{3}{4}'' \times 9''$.

For the theory of the above, see "*Roorkee Manual of Applied Mechanics,*" *Vol I, Chapter XIII*

EXAMPLE XI (*Plate* X)

Let AB *be a beam, with a span of* 24 *feet, the* total *distributed load being* 30,000 *lbs For one of the reasons given above, it is required to truss this beam with two struts, each* $\frac{1}{16}$ *of the span, or* 18 *inches long*

(*See Plate* X, *Fig* II)

Construction of Diagram of central lines of struts and ties

Make AB = 24 feet

Trisect AB in C and D

Drop perpendiculars CE and DF, each = 18 inches

Join AE, EF, and FB

Then—

CE and DF are *struts*

AE, EF, and FB are *tie-rods*

Now of the distributed load, $\frac{1}{6}$ is borne at A, $\frac{1}{3}$ at C, $\frac{1}{3}$ at D, and $\frac{1}{6}$ at B

c = Compression on struts CE and DF

The point C is in equilibrium

Resolve vertically

$\therefore c = \frac{1}{3} \times W$

$= 10,000$ lbs

t = Tension of Tie rods AE and BF

Again the point E is in equilibrium

By symmetry—

Tension on AE = tension on FB

Resolve vertically

$t \cos \text{CEA} = c$

$\therefore t \times \frac{\text{CE}}{\text{AF}} = c$

But $\text{AE} = \sqrt{\text{AC}^2 + \text{CE}^2}$

$= \sqrt{144 \times 64 + 324}$

$= \sqrt{9540}$

$t = \frac{c \times \sqrt{9540}}{18}$

$= 54,263$ lbs

log c = log 10000	= 4 00000
log AE = $\frac{1}{2}$ log 9540	= 1 98977
log numerator	= 5 9 977
log CE = log 18	= 1 25527
log t = log 54263	= 4 73450

t_1 = Tension of Tie-rod EF

log t from above	= 4 73450
log AC = log 96	= 1 98227
log numerator	= 6 71677
log AE = ½ log 9540	= 1 9 977
log t_1 = log 53334	= 4 72 00

Resolve horizontally

$t_1 = t \cos$ CAE

$= t \times \frac{AC}{AE}$

= 53 334 lbs

c_1 = Compression on Beam AC

Again the point A is in equilibrium

Resolve horizontally

$c_1 = t \cos$ CAE

$= t_1$ (from above)

= 53,334 lbs

Calculate dimensions as in previous Examples

PART IV.

CONTRACTS, ESTIMATES, &c.

CONTRACTS.

1 A. C. R. E.'s are advised to carry out all works in their Districts by contract with respectable natives, not only are works executed, as a rule, more cheaply in this manner than by daily labour, but the supervising establishment is thereby saved a large amount of extra work

2 Tenders for all works proposed for execution by contract should be invited in the most public manner possible. This is usually done in practice by posting *ishtihars* on the prescribed form outside the A. C. R. E.'s office, on public notice boards, and by sending copies to the local Civil officers. The date for the reception of Contractors' tenders should be stated, as well as the date on which the work is to be commenced and finished

3 While the *ishtihars* are out, the estimate and plans for the work will be open for the inspection of all persons proposing to submit tenders, and every assistance should be given to the latter, to enable them to understand thoroughly the details of the work, for the execution of which they propose to tender

4 All persons, who submit a tender, should fill in the prescribed form, and when they forward the tender it must invariably be accompanied by the necessary earnest money

5 Tenders should, as far as possible, be opened in the presence of all the tenderers and the result at once made known to them.

6 It is difficult to lay down any fixed rule for guidance in accepting tenders. There is little or no doubt that the practice of accepting the lowest tender in all cases induces Contractors to tender at lower rates and consequently cheapens work. On the other hand, many failures of bad Contractors occur under such a system. Perhaps the best plan is to accept the lowest tender, (when nothing very bad is known against this tenderer) in all cases where there is plenty of time to remedy the

effects of failure, such as in annual repairs, etc. But in cases where a work has to be pushed on energetically and completed within a certain date, it will usually be best to accept the tender of some known and reliable Contractor, *even if it be not the lowest*.

7. A plan often adopted with success is not to allow an unknown or unreliable Contractor to tender for an important work but to make it a rule to accept the lowest tender from among those who have been granted permission to send in tenders.

8. As soon as the tender has been accepted the Contractor should be given written notice of the fact in a book kept for the purpose. At the same time he should be directed to forward his security deposit and be informed of the date on which work is to commence. His signature and that of the Sub Divisional Officer concerned should be recorded in the book against this notice.

9. Contractors are bound to make use of the articles on the Government stock as far as possible. The Contractor is responsible for making himself acquainted with the materials on Government stock and the rates at which such materials will be issued to him before making his tender for the contract. The stock prices of materials issued to him will be deducted *from* his bill or he will pay the money in cash as may be directed by the A. C. R. E.

10. No women are to be employed on any work within the lines of British troops while those lines are occupied by them.

11. Written authority signed by the A. C. R. E. or the subordinate in charge of the work must be produced for any deviation from the measurements or specifications of an estimate. If no such authority can be produced, then the Contractor will be held responsible for the deviation. The measurements referred to are those in the drawings; those in the estimates are for purposes of calculations and not for the information of Contractors.

ESTIMATES.

1 Estimates are of three kinds Rough, Plinth Area or Abstract and Detailed

2 Rough estimates or approximate statements of cost are usually required only in the case of large schemes to enable Government or senior officers to decide whether the scheme is worth further investigation Thus in the case of a proposal to establish a Factory, before sanctioning any particular sum for buildings etc, Government require to have the whole cost of the proposed scheme before them, including land, water supply, buildings, machinery, establishment for working, etc, so that they may decide generally whether the project should be gone on with Such schemes are laid before Government by the department or other senior officers concerned and the preliminary rough estimates are called for through the department or subordinate officers from the Assistant Commanding Royal Engineer of the District

3 It is to be understood, therefore that a rough estimate or approximate statement is not submitted for sanction to a definite sum It must generally in the case of buildings be based on plinth areas, but these need not be accurately taken out In the case of lines for troops, the areas as given in Appendix V, Volume XII India Army Regulations, will be sufficiently near In the case of roads, rates per mile, or rough calculations of the amount of excavation, walling, etc, will generally suffice

4 When Government have decided that the scheme is to be proceeded with, plinth area estimates, in the case of buildings, and abstract estimates, in the case of roads, water supplies, etc, are called for through the Director General of Military Works. These estimates are forwarded to Government for sanction to a definite sum and must therefore be carefully taken out Thus in a plinth area estimate for buildings it must *be decided of what materials the different parts are to be constructed,* how thick the walls are to be, etc, etc

5 The notes on the plinth area estimate form require that the estimate shall consist of a report, a general specification, an explanation as to how the rates are arrived at and the details giving explanation of the buildings required, skeleton plans, plinth areas, rates and amounts

The report should briefly detail the correspondence which has led up to the preparation of the estimate, and should explain how it is proposed to provide the necessary accommodation, and, if any alternatives have been considered, why a particular scheme is recommended, the specification should state of what kind of materials each part of each kind of building is to be constructed

The detail of rates should explain how the plinth area rates have been arrived at

In the detail sheets the buildings should be dealt with in the same order as in India Army Regulations Volume VII, Appendix V In column 3 it should be explained clearly how many men horses, etc, etc have to be provided for and how and in what buildings they are to be accommodated If any existing buildings are to be utilised they should be detailed and outline plans fully dimensioned given of them, as well as of any new buildings proposed

6 In the case of abstract estimates for water supplies etc etc the same general principles should be followed

7 After administrative sanction has been given to a plinth area or abstract estimate technical sanction is required to the detailed estimate, which should include a report, specification, calculations details of measurements and abstract

In such cases the report of the detailed estimate should quote the item of the plinth area estimate and state the amount sanctioned It should describe in general terms the nature of the construction and the kind of materials to be used giving reasons when necessary In an estimate for a work not included in a plinth area estimate the report should give an account of the correspondence leading up to the estimate, and should explain clearly the necessity for the work If desirable, the report should include a description of the methods to be adopted in carrying out the work and the time required to complete it

8 A proper specification must be given for each kind of work included in the estimate either by reference to standard specifications or by writing out the specification in full

9 Explanation should be given of any rates not in the district rate list, or of any deviations from the same

10 On pages 196 to 204 are given samples of abstracts of detailed estimates which should always be followed as regards the arrangements of the items under the various headings of foundations, flooring, roofing, etc, etc

(Specimen)

Abstract of Estimate for Constructing Quarters for a Butcher Sergeant at Allahabad

Items		Quantity	Rate		Amount		
			Cost	Per	Of each Rs	Total Rs	Grand Total
1 Earthwork	c ft	4 155	/8/	%	21	21	
2 Concrete		1 9?6	19/ /		366	366	
3 Brickwork including arches		6 215	28/ /		?40	740	
4 Ashlar		236	1/8/	c ft	354	354	
[illegible] Flooring—							
i Earthwork		1 461	8/	%	7		
ii Concrete		279	19 /		53		
iii Flagging	s ft	1 0 9	20/ /		216		
Average rate for Flooring		1 079	24/10/5		276	276	
6 Plaster		3 581	4/ /		143	143	
7 Roofing—							
i Woodwork	c ft	19?	5/ /	c ft	960		
ii Ironwork	lbs	673	25/ /	cwt	150		
iii Varnishing	s ft	1 ?87	3/ /	%	39		
iv Tiling double		1 391	20/ /		278		
v Whitewashing		1 391	/6/		5		
Average rate for Roofing		1 391	10?/15/1		1 432	1 43?	
8 Doors and Windows—							
i Woodwork	c ft	28	5/ /	c ft	140		
ii Joinery	s ft	258	1/4/	s ft	3 3		
iii Ironwork	lbs	219	25/ /	cwt	49		
iv { Varnishing	s ft	308	3 /	%	[illegible]		
{ Painting		243	3/ /		7		
Average rate for Doors and Windows		258	2/ /8	s ft	528	528	
9 Punkhas—							
i Joists	s ft	2	5/ /	c ft	[illegible]		
ii Framing including hooks ropes &c	s ft	20	2/ /	s ft	40		
iii Blocks with pulleys	No	2	2/ /	each	4		
Average rate for Punkhas	s ft	20	2/4/	s ft	54	54	
10 Whitewashing		4 156	/6/	%	16	16	
11 Bureewashing		1 704	/6/		6	6	
12 Padlock hasp and staple	No	1	2/8/	each	3	3	
13 Dressing ground and surface drains						50	4 989
Add Contingencies at 5 per cent							249
Grand Total							5 238

Cost of each supl ft of plinth area covered $\frac{5238}{1285}$ = 4 07, or Rs 4 1 2¾ per s ft

[*N B* —This is merely given as an Example as to form in details but the rate for any single storeyed building should not exceed Rs 3 0 0 per superficial foot of plinth area covered unless exceptional and good reason can be given]

(Docketing on back of previous Specimen.)

MILITARY WORKS SERVICES

II ALLAHABAD DISTRICT

Abstract of Estimate No of 19 19 ,
of the probable expense of Constructing Quarters for Butcher-Sergeant at Allahabad

For Rupees 5,238

(Specimen.)

ABSTRACT OF ESTIMATE FOR SUBSIDIARY BUILDINGS TO FAMILY QUARTERS, AGRA.

For 4 blocks, to accommodate 34 Families.

	Rate	Unit	Cook house for five families: For one	For two	Cost	Cook house for four families: For one	For six	Cost	Latrine for men: For one	For two	Cost	Latrine for women: For one	For four	Cost	Covered passage: For one	For four	Cost	Grand Total: Quantity	Cost
	Rs a p	c ft			Rs			Rs			Rs			Rs			Rs		Rs
	0 4 0	100	1,006	2,192		877	262	1	517	1,030	[illegible]	590	2,320	[illegible]	477	1,908	[illegible]	12,712	23
	0 4 0	,,	191	[illegible]	1	[illegible]	[illegible]		48	96	1	53	212	1				1,008	5
[illegible]rthwork	0 4 0																	14,[illegible]20	17
	15 0 0	,,	406	812	122	3[illegible]	2,118	318	200	400	60	222	888	133				4,218	633
	23 0 0	,,	411	822	189	357	2,142	493	187	374	[illegible]	209	836	192	521	2,084	479	6,258	1,439
	21 0 0	,,	200	[illegible]	9[illegible]	165	990	2[illegible]	67	134	3[illegible]	72	288	60				1,812	435
	2[illegible] 0 0	,,	1,494	2,[illegible]	742	1,229	7,374	1,844	462	924	231	507	2,028	507				13,294	3,321
	2[illegible] 0 0	,,	35	70	20	33	198	57	18	36	10	18	72	21				370	108
	27 0 0	,,	110	220	59	104	624	16[illegible]	21	42	11	21	84	2[illegible]				970	261
[illegible]rickwork	24 8 3	,,				...												22,710	5,567
[illegible]	1 8 0	c ft	11	22	3	11	66	9[illegible]	1										
[illegible]	1 0 0	,,	63	126	126	52	312	312	4	8	8	4	16	16	100	640	960	728	1,092
																	...	462	162
[illegible]t Stonework	1 4 10	,,	.			..								.	...	.	..	1,190	1,554

5 *Stone Slab set in mortar*				[illegible] ft																	
i [illegible] Stone	14	0	0	100	[illegible]	76	11	[illegible]	278	3?	76	112	10	[illegible]	2?0	[illegible]				672	95
ii 1½	12	0	0		36	72	[illegible]	[illegible]	216	20	25	[illegible]	[illegible]	[illegible]	100	1?				438	53
Average rate for Stone Slab set in mortar	13	0	0																	1 110	118
6 *Flagged [illegible]*																					
i Concrete	1?	0	[illegible]	[illegible]	[illegible]	78	10	31	180	2										204	32
ii Flagging	12	0	[illegible]	[illegible]	11?	[illegible]	2	[illegible]	338	6										790	36
Average rate for [illegible]	10	[illegible]	[illegible]																	70?	125
7 *Lime Plaster and White wash*																					
i Lime plaster		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	3 4??	10		11	[illegible]	[illegible]	220	7?				[illegible]	159
ii Whitewash	0	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	19?		[illegible]	110	1?	[illegible]	[illegible]	1?				[illegible]	15
8 *Painting*	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	9	[illegible]	9 402	[illegible]	[illegible]	[illegible]	4	[illegible]	1 032	9?	3?1	1 404	3	[illegible]	511
9 *Colourwash*	0	[illegible]	[illegible]		[illegible]	112		[illegible]	[illegible] 070	1	[illegible]	[illegible]		727	0?	7				11 30?	23
10 *Terraced [illegible]*																					
i Woodwork	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		12?	13	78	1										110	140
ii Ironwork	1?	0	[illegible]	[illegible]	[illegible]		[illegible]	13	[illegible]	1?										110	2?
iii [illegible]	1?	0	[illegible]	[illegible]	[illegible]	[illegible]	4?	119	[illegible]	100										1 012	142
iv Terracing	7	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	108	[illegible]	70										[illegible]	105
Average rate for [illegible]	70	10																		1 012	71?
Carried over							1 81?			4 ??			?16			1 129			1 479		9,405

Items	Rate	Unit	Cook house for five families: For one	For two	Cost	Cook house for four families: For one	For six	Cost	Latrine for men: For one	For two	Cost	Latrine for women: For one	For four	Cost	Covered passage: For one	For four	Cost	Grand Total: Quantity	Cost
					Rs			Rs			Rs			Rs			Rs		Rs
Brought forward					1 81			4 559			516			1 129			1 479		9 495
11 *Single Tiled Roof*																			
i Woodwork	4 0 0	c ft	2	50	100	20	120	480							179	716	804	886	3 544
ii Ironwork	16 0 0	80 lbs	59	116	2	47	28	63							608	2 072	601	3 0 [illegible]	691
iii Tiling	10 0 0	100 s ft	190	360	[illegible]	162	972	97							1 575	6 300	630	7 652	765
Average rate of Single Tiled Roof	6 5 0																	7 652	5 000
12 *Double Tiled Roof*																			
i Woodwork	4 0 0	c ft							10	20	80	10	40	160				60	240
ii Ironwork	16 0 0	(9) lbs							8	16	4	8	32	6				48	10
iii Tiling	1 0 0	100 s ft							130	260	4	130	520	9[illegible]				780	148
Average rate of Double Tiled Roof	[illegible] 0 5																	780	398
13 *Woodwork* not included under other sub-heads	4 0 0	c ft	321	18	[illegible]9	9	54	216	5	10	40	5	[illegible]0	80				102	408
14 *Ironwork* not included under other sub heads	18 0 0	30 lbs	3[illegible]1	64[illegible]	144	257	1 542	34[illegible]	8	16	3	8	[illegible]	[illegible]				2 [illegible]3[illegible]	501
15 *Doors and Windows*																			
i Doors	1 6 0	s ft	51	42	58	21	126	17										168	231
ii Windows	1 2 0		58	116	131	58	348	[illegible]										464	52[illegible]
iii Fastenings for i and ii	2 0 0	each set	3	6	12	3	18	3										24	48
Average rate of Doors and Windows	1 4 3	s ft																632	801

III *Painting and Varnishing*				s ft																	
i Painting	3	0	0	100	550	1 100	33	439	2 634	79	115	230	7	115	460	14	723	2,892	87	7,316	200
ii Varnishing	2	8	0	"	130	260	1	104	624	16					.					884	23
iii Coal tarring	2	0	0	"	211	422	8	169	1 014	20	9	18	1	9	36	1	158	632	12	2 122	43
17 *Sundries*																					
i Consolidating kankar	4	8	0	100 c ft	59	188	5	48	288	13	109	218	10	109	436	20	214	856	30	1,910	87
ii Chokut-bolts	18	0	0	80 lbs	11	22	5	11	66	15										88	20
iii Boring holes for ii	0	2	0	each	6	12	2	6	36	'										48	7
iv Door seats to latrines	1	2	0	s ft							40	80	30	40	110	180				240	270
Total							2 551			6 510			800			1,690			5,713		17,273
Add Contingencies at 5 per cent							128			325			40			85			286		864
Grand Total							2 642			6 835			840			1,781			5,999		18,137

Cost of each superficial foot of plinth area covered

			Rs	a	p	
Cook houses for five families,	$\frac{2642}{884}$	= 3 07 or	3	0	6½	per s foot
" four "	$\frac{6835}{2196}$	= 3 11	3	1	9¼	" "
Latrines for men	$\frac{840}{204}$	= 4 11 "	4	1	9½	"
" women	$\frac{1781}{408}$	= 4 36	4	5	10	"
Covered passages	$\frac{5999}{3636}$	= 1 65	1	10	5	

(Docketing on back of previous Specimen.)

MILITARY WORKS SERVICES.

MEERUT DISTRICT

Abstract of Estimate No of 19 -19 , of the probable expense of Constructing Subsidiary Buildings for Family Quarters at Agra, for 4 blocks, to accommodate 34 families

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For Rs 18,137.

Date 19 .

(Specimen.)

MILITARY WORKS SERVICES.

MEERUT DISTRICT.

General Abstract of Estimate of the probable expense of Constructing Subsidiary Buildings for Family Quarters at Agra, for 4 blocks

Names of Buildings	Plinth area of buildings	Rate per square foot of plinth area			Cost of buildings	Grand Total Cost
	Sq ft	Rs	A	P	Rs	Rs
2 Cook houses for five families	884	3	0	6½	2,682	
6 " " four "	2 196	3	1	9½	6,835	
2 Latrines for men . .	204	4	1	9½	840	
4 " " women ..	408	4	5	10	1,781	
Covered passages	3 636	1	10	6	5,999	
		Grand Total Cost				18,137

I The above estimate includes charges for work Establishment Tools and Plant, etc

II The work will be executed by Contract, and will be completed within 9 months

III Funds are not allotted in Budget for current year for this work, and an appropriation is solicited to the extent of Rs 18,137.

IV Total of Estimate Rs 18,137

Deduct values of Stock issues " 8,137

Balance cash required " 10,000

(Docketing on back of previous Specimen.)

MILITARY WORKS SERVICES.

MEERUT DISTRICT.

General Abstract of Estimate No. of 19 -19 , of the probable expense of Constructing Subsidiary Buildings for Family Quarters at Agra, for 4 blocks

For Rupees 18,137.

Date 19 .

PART V.

RATES.

RATES.

1 Many circumstances, such as no two workmen executing the same amount of work in the same amount of time combine to render the preparation of really accurate details of rates a matter of much difficulty involving the expenditure of considerable time and labour

2 Under a good contract system where contractors really compete for the execution of a work the exact accuracy of the rates becomes a matter of secondary importance For if the rates are too high the tenders will be proportionately low

3 The above is however probably only true to a limited extent, while at many stations there is little competition among contractors, and work has often to be done by daily labour. It therefore becomes important that rates should be as accurate as time and circumstances will permit

4 With a view to render some assistance towards attaining this result, the information contained in the following pages is given

5 The tasks a skilled workman can perform may be of assistance where works are being executed by daily labour

6 The rates in use at the present time at important stations in the different Districts are given for the more common kinds of work, as they may sometimes be useful for comparison

7 Details of work for several items in constant use are also given as a guide and check when drawing up similar details for the same kinds of work at other stations the rates given in these details should not be taken as accurate

Task for an experienced Artizan per diem

Brickwork	15	cubic feet
Flat archwork	8	"
Circular "	7	"
Honey-comb work	25	"
Coursed rubble masonry	5 to 10	"

Random-squared coursed rubble	5 to 12 cubic feet
Random coursed rubble	up to 15 ,,
Dressed ashlar	1 to 1½ ,,
Ashlar in arches	1 to 1½ ,,
Plastering, 1 coat	60 s. feet
,, 2 ,,	30 ,,
,, 3 ,,	20 ,,
Pointing	100 ,,
Terraced floors or roofs	50 ,,
Brick-on edge flooring	45 ,,
Flagged flooring	20 ,,
Allahabad tiling, single	35 ,,
,, ,, double	15 ,,
Fixing roof battens	100 ,,
1 pair batten doors (4 × 7)	8 days
Teak wood framing, &c	1 cubic foot
1 pair panel doors	15 days
1 ,, ,, Venetian doors (4 × 7')	18 ,,

Load for a two-bullock cart

Bricks (9 × 4½ × 2¾)	250
Broken stone	15 cubic feet
Gravel	15 ,,
Kankar lime	13 ,,
Slaked ,,	45 ,,
Sandstone	9 ,,

DETAILS OF COST OF WORK.

DISTRICT—*Garhwal* STATION—*Dehra Dun.*

Name of Work—*Concrete in Foundations*

Details of Labour and Materials per 100 cubic feet		No or quantity	Rate Cost	Rate Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
Mason	No	1	/6	diem	0	6	0						
Beldars		12	/3/	"	2	4	0						
Coolies	"	12	/2/		1	8	0						
Bhisties	"	2	/3/		0	6	0	4	8	0			
Materials													
Brick or stone ballast	c ft	110	6/ /	%	6	9	7						
Stone lime	"	16	23/ /	"	3	10	5						
Bajri washed	"	24	5/ /	"	1	4	0						
Goor &c					0	4	0	11	12	0			
Total Labour and Materials											16	4	0

DETAILS OF COST OF WORK

DISTRICT—*Meerut* STATION—*Meerut.*

Name of Work—*1st Class Brickwork in Lime Mortar.*

Details of Labour and Materials per 100 cubic feet		No or quantity	Rate Cost	Rate Per	Amount Rs	Amount A	Amount P	Total Rs	Total A	Total P	Grand Total Rs	Grand Total A	Grand Total P
Labour					Rs	A	P	Rs	A	P	Rs	A	P
Bricklayer mistri	No	½	/12/	each	0	[illegible]	0						
Bricklayers		5	/5/		1	9	0						
Beldar mate		[illegible]	/3/		0	1	0						
Beldars		3	/2 6		0	7	6						
Coolies		6	/2/		0	12	0						
Bhisties		2	/2/6		0	5	0						
Scaffolding &c					0	7	0	3	12	6			
Materials													
Bricks 9½ × 4½ × 2¾	No	1400	10/	o/oo	14	0	0						
Cartage of do 2 miles		1400	1/4/		1	12	0						
Kankar lime pure	c ft	30	31/ /	o/o	9	4	10						
Cartage of do 2 miles		30	1/ /		0	10	10	[illegible]	11	8			
Contractor's profit &c								0	7	10			
Total Labour and Materials											30	0	0

DETAILS OF COST OF WORK.

DISTRICT—*Lucknow* STATION—*Lucknow*.

Name of Work—*Cut stone finely dressed in verandah pillars and door frames.*

Details of Labour and Materials per cubic foot		No or quantity	Rate Cost	Rate Per	Amount Rs	Amount A	Amount P	Total Rs	Total A	Total P	Grand Total Rs	Grand Total A	Grand Total P
Labour													
Mason	No	$\frac{8}{5\frac{1}{2}}$	/6/	each	0	8	9						
"	"	⅙	/6/	"	0	1	0						
"	"	⅛	/6/	"	0	0	9						
Beldar	"	¼	/3/-		0	0	9	0	11	0			
Materials													
Rough stone in blocks at quarry station	c ft	1	/8/-	c ft	0	8	0						
Railway freight		1	/6/9	"	0	6	9						
Unloading at station and cartage say 2 miles		1	/1		0	1	0						
Sundries					0	1	6	1	1	3			
Total Labour and Materials											1	13	0

DETAILS OF COST OF WORK

DISTRICT—*Bareilly* STATION—*Bareilly*

Name of Work—*Lime Plaster with Pure Kankar Lime on Brickwork*

Details of Labour and Materials per 100 superficial feet		No or quantity	Rate Cost	Rate Per	Amount Rs	Amount A	Amount P	Total Rs	Total A	Total P	Grand Total Rs	Grand Total A	Grand Total P
Labour													
Mason	No	1½	/5/	each	0	7	6						
Coolies		4	/1/6	,,	0	6	0						
Bhisties	,,	½	/2/6	,,	0	1	3						
Beldars		½	/2/6	,,	0	1	3						
Mixing—Bullocks		¼	/4/		0	1	0	1	1	0			
Materials													
Kankar lime	c ft	6	28/ /	%	1	10	10						
Sundries					0	0	2	1	11	0			
Total Labour and Materials											[illegible]	12	0

DETAILS OF COST OF WORK

DISTRICT—*Meerut* STATION—*Agra*

Name of Work—1½" *Flagged Flooring on 3" Concrete*

Details of Labour and Materials per 100 superficial feet		No. or quantity	Rate Cost	Rate Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
I *Concrete*—													
Beldars	No	3	/2/6	each	0	7	6						
Coolies		2	/1/6	„	0	3	0						
Bhisties		1½	3		0	4	6						
Grinding mortar	c ft	11½	1/14/	%	0	3	6	1	2	6			
Materials													
For Ballast—													
Clean washed kankar		28	5 8/		1	8	6						
„ bujree		10	11/		1	1	[illegible]						
For Mortar—													
Ground and sifted kankar lime		4½	24 /		1	1	3						
Clean washed bujree		7	11/ /		0	12	3	4	7	6			
Total Labour and Materials											5	10	0
Labour													
II 1½" *Flagged Flooring*—													
Stone masons	No	[illegible]	[illegible]	each	1	9	0						
Beldars		3	2 6		0	[illegible]	6						
Coolies		2	1 6		0	3	0						
Bhisties		1	3		0	3	0						
Grinding mortar	c ft	1[illegible]	1 14		0	4	6	2	11	0			
Materials													
Stone slabs	s ft	110	9		9	14	3						
Kankar lime	c ft	6	24		1	7	0						
Washed bujree		9	11		0	15	10	12	5	1			
Total Labour and Materials											1[illegible]	0	0
Total for 1½" Flagged Flooring on 3" Concrete											2[illegible]	10	0

DETAILS OF COST OF WORK

DISTRICT—*Rawalpindi* STATION—*Rawalpindi*

Name of Work—*Patent Stone Flooring 1 thick*

Details of Labour and Materials per 100 superficial feet		No or quantity	Rate: Cost	Rate: Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labours													
Mistri	No	⅛	1/ /	each	0	2	0						
Mason	,	1	/10/	,	0	10	0						
,	,,	1	-/9/	,,	0	9	0						
Coolies	,	3	/4/	,	0	12	0						
,		2	-/3/	,	0	6	0						
Bhistie	,	1	5/	,,	0	5	0	[illegible]	12	0			
Materials													
Slag { 1 Stone / 1 Jhama }	c ft	12	6/	c ft	4	8	0						
Portland cement	Brl	1	15 10/	brl	15	10	0						
Thapies, hard wood	No	2	/2/-	each	0	4	0						
Sieve	,,	½	-/8/	,	0	4	0						
Wooden frames	Job				0	6	0	21	0	0			
Total											23	12	0
Add Contractor's profit @ 5 %											1	3	0
Grand Total											24	15	0
Say											25	0	0

N B—As the jhama is of a very porous absorbent nature the aggregate should be thoroughly wetted otherwise it will suck all the moisture out of the cement and greatly reduce its strength

The slag supplied by the Indian Patent Stone Company contains iron slag, the above slag is of local manufacture

DETAILS OF COST OF WORK

DISTRICT—*Rawalpindi* STATION—*Rawalpindi*

Name of Work—*Flooring laid with Machine Pressed Tiles* 9 × 9 × 2

Detail of Labour and Materials per 100 superficial feet		No or quantity	Rate Cost	Rate Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
Mason	No	1	/12/	each	0	12	0						
"		1	/10	"	0	10	0						
Coolies		2	/4/	"	0	8	0						
Mistri		¼	1/		0	4	0						
Bhistie	"	1	5	"	0	5	0	2	7	0			
Materials													
Tiles		187	20 /	°/oo	3	11	10						
Carriage of Tiles		187	3 /	°/oo	0	9	0						
Mortar	c ft	6	4/	c ft	1	8	0						
Carriage of mortar		6			0	2	0	5	14	10			
Contractor's profit								0	10	2			
Total Labour and Materials											9	0	0

DETAILS OF COST OF WORK.

DISTRICT—*Garhwal* STATION—*Chakrata*

Name of Work—1½ *Deodar Flooring including Joists*

Details of Labour and Materials per 100 superficial feet		No or quantity	Rate Cost	Rate Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
Carpenters	No	8	8	each	4	0	0						
Coolies		8	4		2	0	0	6	0	0			
Materials													
Joists 5 × 10 × 4 × 6	c ft	8½	1/12	c ft	14	9	4						
1½ Planks 110 s ft		13¾	1 8		20	10	1						
4 Nails	cwt	¼	17/8/	cwt	2	8	0						
Coal tar		⅛	11		1	6	0	39	1	5			
Total Labour and Materials											45	0	0

DETAILS OF COST OF WORK

DISTRICT—*Meerut* STATION—*Agra*

Name of Work—*Framing sal wood work*

Details of Labour and Materials per cubic foot.		No or quantity	Rate. Cost	Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
Sawyer	No	1	-/5	each	0	5	0						
Beldars		2	2 [illegible]	„	0	5	0						
Carpenters		1½	-/5		0	7	6	1	1	6			
Materials													
Sal wood in log including 45 per cent of out turn as loss	c ft	1	3/4/-	c ft	3	4	0	3	4	0			
Total Labour and Materials including framing in position											4	5	6

Remarks and Explanations

Cost in log varies at Agra from Rs 2 3 to Rs 2 4/ per cubic foot measured according to girth formula Add to this about 45 per cent loss say Re 1/ cost of cubic foot becomes say Rs 3 4

DETAILS OF COST OF WORK

DISTRICT—*Meerut* STATION—*Meerut*

Name of Work—*Making and fixing 1½" glazed teak wood Doors*

Details of Labour and Materials per 300 superficial feet		No or quantity	Rate Cost	Rate Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
Carpenter mistri		5 m	20 /	month	13	5	4						
Carpenters	No	270	/6	each	82	8	0						
Sawyers		32	/6/		12	0	0						
Beldars		20	/2 6		3	2	0						
Cart (carting doors to site)		1	1/ /		1	0	0	111	15	4			
Cost per superficial foot Labour $\frac{111\ 15\ 4}{300}$ =											0	5	10
Materials													
Teak wood	c ft	53 48	3 2/	c ft	170	[illegible]	0						
Doors bolts 1½ feet	No	8	/9	each	4	8	0						
1 foot		8	/6		3	0	0						
Hinges 6"		48	4/8	doz	18	0	0						
3" (for cleat)		16	1/4		1	10	[illegible]						
Screws 1½"	gr	4	/12	gross	3	0	[illegible]						
1"		1	/8		0	8	0						
Glazing	No	96	/5	each	30	0	0						
Glue					0	8	0	231	8	8			
Cost per superficial foot Materials = $\frac{231\ 8\ 8}{300}$ =											0	12	4
Total cost per superficial foot											1	[illegible]	2

DETAILS OF COST OF WORK

DISTRICT—*Madras* STATION—*Wellington*

Name of Work—1 *Teak wood battened door*

Details of Labour and Materials per 15 superficial feet		No or quantity	Rate		Amount			Total			Grand Total		
			Cost	Per									
Labour					Rs	A	P	Rs	A	P	Rs	A	P
Carpenter mistri	No	½	1/8/	each	0	8	0						
Carpenters		8	/14/		7	0	0						
Coolies		3	/5/		0	15	0	8	7	0			
Materials													
Teak wood— 6 × 6 × 5½ × 1 = 1 37 3 × 2½ × 5½ × 1 = 0 27 2 × 2¾ × 5½ × 1 = 0 21 1 85	c ft	1 85	3 8	c ft	6	7	7						
Iron hinges 4	No	3	/4/	each	0	12	0						
Iron tower bolts 6		2	4		0	8	0						
1½ Iron screws Nettlefolds No 12	gr	½	12	gross	0	6	0						
Iron hasp and staple	No	1	12	each	0	12	0	[illegible]	13	7			
Add Contractor's profit @ 10 % on labour and teak wood Rs 14 14 7								1	7	10			
Total Labour and Materials											18	12	5
Per s											1	4	0

DETAILS OF COST OF WORK

DISTRICT—*Lucknow* STATION—*Lucknow*

Name of Work—*Ironwork Straps Bolts, &c, &c*

Details of Labour and Materials per cwt		No or quantity	Rate		Amount			Total			Grand Total		
			Cost	Per									
Labour					Rs	A	P	Rs	A	P	Rs	A	P
Smith	No	1	/8/	day	0	8	0						
		23	/6/		8	10	0						
		6	/2/6		0	15	0						
Bellars		III	/2 6		2	13	0						
		6	/2 3		0	13	6	13	11	0			
Materials													
Iron rods [illegible]	cwt	qr 0 3 0	7 8	cwt	16	14	0						
[illegible]		qr lbs 0 1 14											
Iron flat 1¼ × [illegible]		1 0 14											
Iron nuts [illegible]" × [illegible]"		12	4/	11	3	0	0						
Coals	md	3	/7/	md	1	5	0	21	3	0			
Grand Total											34	14	6
Rs 34 11-6 ÷ 2—1—4 (Cwt qr lbs) = per cwt											15	4	4
Cost of fixing &c											2	0	0
Total											17	4	4
Say											17	8	0

DETAILS OF COST OF WORK.

DISTRICT—*Bareilly* STATION—*Bareilly*

Name of Work—*Double Allahabad Tiling with 1st Class semi hexagonal Tiles.*

Details of Labour and Materials per 100 superficial feet		No or quantity	Rate Cost	Rate Per	Amount Rs	Amount A	Amount P	Total Rs	Total A	Total P	Grand Total Rs	Grand Total A	Grand Total P
Labour													
Masons	No	6	/5	each	1	14	0						
Coolies		6	–	„	0	12	0						
Cart	„	1	8/		0	8	0	3		[illegible]			
Materials													
Tiles flat 1st class upper layer		110	30	%	3	4	0						
Tiles half round		110	25		2	12	0						
Tiles flat 2nd class lower layer		110	20/		2	3	2						
Tiles semi hexagonal 1st class		110	25		2	12	0						
Tiles ridge ventilator		4	60		0	3	9						
„ „ elbow		4	50		0	4	2	11	6	10			
Total Labour and Materials											14	8	10
Or say											14	10	0

DETAILS OF COST OF WORK

DISTRICT—*Bareilly* | STATION—*Bareilly*

Name of Work—*Single Allahabad Tiling with 1st Class Tiles*

Details of Labour and Materials per 100 superficial feet		Number or quantity	Rate Cost	Rate Per	Amount Rs	A	P	Total Rs	A	P	Grand Total Rs	A	P
Labour													
Mason	No	3	5/	each	0	15	0						
Coolies		3	2		0	6	0						
Cart		½	8/	"	0	4	0	1	9	0			
Materials													
1st class flat tiles		110	30/	%o	3	4	9						
1st class half round tiles		110	25/		2	12	0						
1st class ridge ventilator		4	60		0	3	9						
1st class ridge elbow		1	0		0	3	2	6	7	8			
Total Labour and Materials											8	0	8
Or say											8	-	0

DETAILS OF COST OF WORK

DISTRICT—*Bareilly* STATION—*Bareilly*

Name of Work—*Sheet Iron Roofing, Naini Tal system (improved pattern without any exposed screws)*

Details of Labour and Materials per 100 superficial feet.		No. or quantity	Rate: Cost	Rate: Per	Amount Rs	a	p	Total Rs	a	p	Grand Total Rs	a	p
Labour													
Carpenters	No	3½	8/	each	1	12	0						
Blacksmiths		1	8/		0	8	0						
Painters		2	3		0	6	0						
Coolies		3	2 8		0	8	0	3	2	0			
Materials													
Iron sheets (6′×2′) (22 B W G)	„	11¼	1 10	each	18	4	0						
Iron sheets (6′×2′) (18 B W G)		1¼	2 8	„	3	6	0						
Fir planking 1″ including nails and screws	ft	100	6 6		6	6	0						
Iron clips catches rivets &c	seer	6	7	each	2	10	0						
Olylert's metallic paint	lb	2	2	lb	0	4	0						
Linseed oil		2¼	6		0	13	6						
Coal tar		1¼	2		0	2	6	31	14	0			
Total Labour and Materials											35	0	0

DETAILS OF COST OF WORK

DISTRICT—*Presidency.* STATION— *Lebong and Ishapore* { *Mean between cost at*

Name of Work—*Galvanized Sheet Iron Roofing, Le Mesurier system*

Details of Labour and Materials per 100 superficial feet		No or quantity	Rate		Amount			Total			Grand Total		
			Cost	Per	Rs	A	P	Rs	A	P	Rs	A	P
Labour													
Carpenters	No	2	1/ /-	each	2	0	0						
Coolies	"	2	/5/		0	10	0						
Labour for making clips eaves and ridge hooks					2	1	0						
Labour for bending sheets					0	12	0	5	7	0			
Materials													
Galvanized Iron Sheets 22 B W G 126 s ft	cwt	1½	11 8/	cwt	17	4	0						
Hoop steel galvanized 1½ × 14 B W G (for clips, &c)	cwt	[illegible]	11	"	1	0	0						
1½ screws	No	54	/10	gross	0	3	9						
¾ screws	"	36	6/	"	0	1	0	18	0	3			
Total Labour and Materials											24	0	3

Note—The above is a mean between the cost of laying with 8 × 3 sheets (at Ishapore) and 10 × 2 sheets (at Lebong)

DETAILS OF COST OF WORK

DISTRICT—*Meerut* STATION—*Meerut*

Name of Work—*Painting Doors and Windows with 3 coats of Chocolate silicate paint*

Details of Labour and Materials per 1360 superficial feet		No or quantity	Rate Cost	Rate Per	Amount Rs	Amount A	Amount P	Total Rs	Total A	Total P	Grand Total Rs	Grand Total A	Grand Total P
Labour													
Painters	No	34	/4/-	each	8	8	0						
Beldars	"	4	-/2 6	"	0	10	0						
Coolies	"	1	/1 6		0	1	6	9	3	6			
Total Labour per 100 s ft $=\frac{9\ 3\text{-}6}{13\ 60}=$											0	10	9
Materials													
Chocolate paint	lbs.	50	29 -	cwt	12	15	11						
Patent driers	"	5	49/-	"	2	3	0						
Linseed oil raw	gals	2	3 2 5	gall	6	4	10						
" " boiled	"	2	3 4 5		6	8	10						
Turpentine	"	½	3 1 6	"	1	14	11						
Paint brushes	No	2	8	each	1	0	0						
Gharras		2	1 3		0	2	6						
Cloth	yd	1	2	yard	0	2	0	31	3	[illegible]			
Total Materials per 100 s ft $=\frac{31\ 3\ 2}{13\ 60}=$											2	4	8
Total cost per 100 s ft											2	15	5

STATEMENT SHOWING THE BATES FOR VARIOUS KINDS OF WORK IN THE

Item Number	Sub-heads	Per	Punjab						
			Rawalpindi	Murree	Lahore Cant	Umballa	Kasauli	Meerut	Ranikhet
	Demol t on								
1	Floors of bricks concrete or stone	°/o c ft	1/ /	1/ /	1/ /	/8/	1/ /	/8/	/4/
2	Roofs tile l		1/	1/ /	/14	/12/	1/ /	/4/ to /8/	4/
3	Roofs terrace l		1/	1/ /	/8	1/ /	1/ /	/8	
4	Walls i i mortar	°/o c ft	1/ /	1/ /	1/ /	1/ /	1/ /	1/ /	/1?
5	in i u l		8/	1/ /	/10/	/12	/12/	/12	/6
	Earthuo k								
6	Ea rtl ork filling an l ramn i g	/ o c ft	5 /	6/ /	5/ /	3 /	3/ /	10/ /	6 /
7	Excavat on in eartl for foun ls		4/ /	5/ /	5/ /	3/ / to 5 /	7/ /	2 8	5/ /
8	rock har l		15/	19/ /					12 /
9	soft		[illegible]	14					8 /
10	Well s uking to water level	o c ft	4 8			4 8			
11	in v ater a l clay		12			12			
	Concrete								
12	Br ck ballast in l n e for foun lation an l floors	/o c ft	17	?0 /	20/ /	20 /		14 2	
13	Stone ballast in l me	"	16	16 /		?8 /	30 14		2? /
	Br ckwork								
14	In l me mortar 1st class	°/o c ft	29 /		21 /	2? /		25 8	
15	2n l		?1 1?		21	21/ /		20 8	
16	clay 1st	"	21/4		16 /	18		18 8	
17	2 l		16 12		13	14 /		13 /	
18	Sun lried	"	6		4 /	14		5 /	
19	l me archw rk 1st class		40		21	32 /		30 /	
20	Fire bri k in fire clay		450	400 /	?00 /	20? to 349	330 to 449	400 /	"
	Stone Masonry								
21	Ashlar work	c ft	1	1/ /					
2?	Coursed rubble in l me	o c ft	31/	26			3? to 4?		24 /
2?	" in c ay			17 8			20 to 23		11 8

PRINCIPAL STATIONS IN THE MILITARY WORKS SERVICES

Bengal				Madras				Bombay			
Allahabad	Lucknow	Fort William	Darjeeling	Secunderabad	Madras	Bangalore	Wellington	Quetta	Poona	Belgaum	Aden
1/ /	/8/ to 1/	2/ /			/9 to 1/8/	/8	1/ to 2/8/	/12			
-/12/	/12/	12/		1/8	/12	/8/	1/ /		2/ /	1/ /	
1/ /	1/ /	2 /		1/8/	2	6					
1/ /	/12	2 /	2/ /	2 /	1 10/	12	2 8	12	2 /	1/4/	1/ / to 4/ /
8/	/8/	1/ /		1/8/	/12 6	10	2 8	8	1 8/		
5 /	5/ /	5	10 /	5 /	8 /	1/2	10	3 8		10 /	15 /
5 /	5/ /	5/	5	7	3 14	5	8	5 4	10	5 /	20 /
			10/ /					14	100	7 /	120/ /
				15 /	13 8			21 to 2	15		
		1/8/	[illegible]	3/ /	1 8						
4 /	4/ /				2 8						
18	18 /	2[illegible]/		15 /	14 to 15		20				
20 /			20	16	1 to [illegible]	1	5	1	15 8	10	18/ /
24/ /	24/ /	[illegible]8		23 /	23 12	26	35 4	33 5 4	27		70 /
21/ /	21/ /	26		18	1	18	29 12	28	30		
18/ /	17/8/			18	0 12	0 4	26 4	25 8	15		
15 /	15 /	10 /		14	14	13	20 4	20			
5 /	5 8	6		3	6 1	4 12	8	-	8		
30 /	29 /	42 /		2	20 8	32	40	43 5 4	32		..
250/ /	250	175 /	331/		231 4		35 8	2 1 4	350		250/ /
				1	2 to 2 8	1 8	5	1	1		
			35	20 /-	150	4	42	34	23	30	24 / to 45 /
	..		22 /	16	100	22	15	16	9		

STATEMENT SHOWING THE RATES FOR VARIOUS KINDS OF WORK IN THE

Item Number	Sub-heads	Per	Punjab						
			Rawalpindi	Murree	Lahore Cant	Umballa	Kasauli	Meerut	Ranikhet
24	Cut stones bed plates and corbels	c ft	2 /	2 /		1/8/	1/6/	2/8/	1/ /
25	Dry rubble masonry rough	% c ft	to 16	12/ /			8/8/		4/ /
	Flooring								
26	Asphalte ½ thick	% s ft	30 (1)	31 / (1)	32/ / (1)	40 /	40	36 /	
27	Brick on edge excluding concrete		12 8		11	13		12 8/	
28	Brick flat		7 10	25 /	7/ /	7/8		7/12/	
29	Flagged ½		24 /	22 /	24 6/	30/ /	35/ /	25 8/	50 /
30	Indian stone Patent 1 thick		50				49/ /		
31	Terraced 3		6 /	6 /				5/ /	
32	4"		7 8	7 8					10 /
33	6		12	12 /	10 /				
34	Rammed earth in stables &c		2 /	2 8	1/8/	2 2	2 /	3 /	2
35	I C concrete 1 on 3 lime concrete								
	Plaster and Pointing								
36	Leeping (cow dung) fine	% s ft	/1	2	/1/-	1/	/1/	/1/	2
37	Plaster lime on brick walls		2 8	3	2 4	2 8		3 /	
38	stone		4 /	4 /			4 8		4 /
39	I C ½ thick		6 /	8 12/	4 /	6 /	6 8	7/ /	11/4
40	mud inclusive of leeping		8	9	6	/5	/10 -	6	1 /
41	Lime pointing new walls		1 8	2 8	1/8	1 8		1/12	
42	[illegible] thick walls	"	3 /	3 /			2 12	2 /	1/12
43	I C [illegible] brick walls	"	4 4	5	2 8	2 8		3 /	
44	Scraping walls		1/	1/	/1 6	/1/	/1/	/1 6	2 6
	White and Colour washing								
45	Whitewashing 1 coat		1 3	1 9	1 6	1 8	[illegible]		
46	[illegible]				[illegible]	3	3 6		[illegible] 2

PRINCIPAL STATIONS IN THE MILITARY WORKS SERVICES

Bengal				Madras				Bombay			
Allahabad	Lucknow	Fort William	Darjeeling	Secunderabad	Madras	Bangalore	Wellington	Quetta	Poona	Belgaum	Aden
1 8 to ?/8	1 8 to 1 14	2 8	1 /		? 8			2/14/	1/ /	2/8	2/8/
			15/ /	14/ /	13/ /		10/ /	9/ /	7/ /	8 /	8/8/ to 12/ /
		18/ /		3o/ /	18 8/	30/ / on 4 concrete	37/8/		50/ /		
10 /	10	14 8/			8/14/		11/8	17/1?/			
7 8/	7 8	11/ /			8 8/ to 16/ /			12/12			
17/ /	20 8/			15	17 8	18 / on 3 concrete	30/4/	42/4/	21/ /		
		20/1?						17/1?/			
		12/ /			4/6/		6/4/			6/ /	9/8/
		14/ /			5 10	6 4/				8/ /	11/ /
		16/ /			8/4/			13 /		12 /	18/-/
1 8	? /	1 /	1	5 4	6 /		10 /	3 /	2 8/	3/4	3/ /
		3 /				10 /					?0/ / 2 P C 4 Lime
/ /6	/1/	/5/			/1/		/1 6	/?/	/ /9	2	
3 /	3/ /	2 10/		3 8/	? 8/	? 4/	4/4	4 8/	5 /	4 /	
			[illegible] /	4 8	3 /				6/8	6 8	8/ /
3/ /	6 /	4 4	16 8 (1)	10 /	6 4 (4"	5 8	10 4 (4")	6 /	4 /	4 /	5/ /
/8/	/o	/10/		1/ /	/14	/8	1 8	/10	1/6	1/ /	
1 8	1/8	2 8		1/14	1 /	1/4	1 8	2 8	3 /	[illegible]	
			3/ /	1/10	1	1 8			2 8		1 o to 2 8
3/ /	3 /	3 8	6 /	3 13	3 8		4 ?	3	3 8	3 8	5 / to ?/
/1/6	/1 6	2 6	3 ?	1/	1 6		1?	1/	?3	4	3
1/6	/1 6	2 4	3 6		/1 6	1?	? 6	?	1 6	1	?2
2 6	/? 6	/4	6 ?	?	? 1	2 6	?3 6		?	?	/4

STATEMENT SHOWING THE RATES FOR VARIOUS KINDS OF WORK IN THE

Item Number	Sub-heads	Per	Punjab						
			Rawalpindi	Murree	Lahore Cantt	Umballa	Kasauli	Meerut	Ranikhet
47	White washing 3 coats	°/o s ft	/3/	/3/	/3/6	/4/	/5/	/3/6	/5/
48	Colour washing 1		–		/2/	/2/		/3/	
49	" 2		/4/	/4/6	/4/				/5/
50	" 3				/6/				
	Woodwork Carpentry and Joinery								
51	Teak in framing beams &c	c ft			4/ /				
52	Sal					3/8/		4/4/	
53	Chir					1/6/	1/9/6		1/2/6
54	Deodar		2/ /	3/ /	1/14/	2/4/	2/1/		
55	Teak doors and windows framed and glazed 1½	s ft						1/2/	1/6/
56	Teak doors and windows battened 1½								
57	Deodar doors and windows framed and glazed 1½		1/ /	/12 Bar	/14/	/14/	/14/6	/12/	/13/3
58	Deodar doors and windows battened 1½		9	/9/ Bar	/8/	/13/	/14/		/8/ Chir
59	Boarded floor plain 1½" tongued and grooved	°/o s ft	28/ / Deodar	30/ Bar	35/ Deodar	30/ /	32/ /	20/ /	20/12 Chir
	Iron work								
60	For trusses mild steel	cwt	17/8/	19/ /		12/8/	13/8/		
61	" bolts straps etc W I		21/ /	22/6/	19/9/6	21/ /	22/6/	19/ /	20/ /
62	Rolled steel joists		14/ /	14/12/		11/8/	12/8/		
63	Cast iron work		14/ /	16/12/		14/ /	16/12		
	Brasswork								
64	Brasswork filed and fixed	lb	/12/	1/4/		/10	/12/	/12/	
65	Copper		1/ /	1/4/		/12/	/14/		
	Painting and Glazing								
66	Painting 1 coat Europe	°/o s ft	1/4/	1/6/	1/ /	/15/	1/ /	/12/	/14/
67	" 2		2/ /	2/4	1/11/	1/12/	1/14/	1/8/	1/12/
68	" 1 priming and 2 coats finishing		2/8/	3/ /	2/6/	2/4/	3/ /	2/ /	2/8/
69	Painting ironwork 1 coat oxide iron		1/ /	/14/	/9/	/6/	/7/		/12/
70	Varnishing 1 coat		1/ /	1/4/	/10/	1/4/	1/4/	/14/	

PRINCIPAL STATIONS IN THE MILITARY WORKS SERVICES

Bengal				Madras				Bombay			
Allahabad	Lucknow	Ft William	Darjeeling	Secunderabad	Madras	Bangalore	Wellington	Quetta	Poona	Belgaum	Aden
3 6	3 6	5	8 9	3 3	3		4/6	/5	/4/	/3/	
/2/	/	3			/2		/3/	/2 6	/6/	/1/6	/3/
/3/6	/3/6	/5/6		/3 3	/3/	/2/9	/4/	/5/	/12/	/3/	/5/
/4/6	/4/6	/8/	/8/	/4/	/4/		/5/	/7/6	1/2/	/4/6	
5/ /	4 8/	3 12 0		4/8/	3 12 to 4/ /	3/12/	5/ /	4/4/	3/6/ to 4 6	4/4/	5/8/
4/ /	3 12 to 4 /	3/4/0									
1/ /	1 /	/15/	1/2	1/3/	/12/	12/6	1/2/	2 3 to 2 12 1/5	1/7/	1/8/	4/8/ Ben teak 2/4/
/14/	/14/	/11/ 1		1/2/	/9 6	/11/6	/14/6		1/4/	1/4/	2/ /
								/12/			1/12 Ben teak
								/11/6			1/6 Ben teak
75 Teak	68 12 Teak	62 8		64 /	53 /	48 /	68/ /	46/	[illegible] Teak		47/ / Ben teak
15/ /	15 /	13 /	18/ /	31/ /	1/ /	15 8	28/8/	17/8/			
15 /	15 /	25 /	31/ /	21/ /	24/8/	21/ /	28/ /	19 4	21/ /	17 8	25 /
	10 /			8 /	10 /	10 8	13 /	7/ /	8 8		
		9 /	1	14 /	12 / to 18 /	15 /	14 to 20	14 /	7/ /		12 /
					/12 6		1/-/	1 8 -	8		1/12
					1/ /		1/4		/11		1/4
1/8	1 12	/9	/11 6	1 4	1/ /	1 4	1 4	10 6	1 6		1 4
3/ /	2 8	1/2	1/7/-	2	1/10	1 14	1 14		2 12	2	2 4
	3 4	1/12	2 3 6	3 /	2 9	2 6/	3/ /	2 8	4 4 -	2 8	2 12
/14	/10	/9	11/6	/14	9	8 -	11/	6			1 4
1/6	1 6	1 8	1 10 6		1/6/	–	1 12	1 5	1 -	12/	1/12

STATEMENT SHOWING THE RATES FOR VARIOUS KINDS OF WORK IN THE

Item Number	Sub heads	Per	Punjab: Rawalpindi	Punjab: Murree	Punjab: Lahore Cant.	Punjab: Umballa	Punjab: Kasauli	Meerut	Ranikhet
71	Varnishing 2 coats	% s ft	1/12/	2/ /	1/8/	2/10/	2/12/	1/8/	2/8/
72	Coal tarring 1		/10/6	/11/	/10/	/8/	/9/6	/10/	/8/
73			1/3/	1/4/	1/ /	/14/	1/ /	1/ /	1/ /
74	Wood oiling 1		/4/	/4/					/8/
75	2								/12/
76	Letters and figures under 3	each	/1/6	/1/6	/ /6	/1/6		/ /6	/4/
77	Renewing Glass 8 × 10	each	/3/	/4	/3/	/3/6	/4/6	/3/3	/3/3
78	10 × 12"		/4/6	/5/6	/3/	/4/6	/5/	/5 6	/4/
	Roof Covering								
79	Double Allahabad tiling 1st class	% s ft	21/ /		34 /	21/8/		17/8/	
80	Single		12/4/		17/ /	11/ /		9/8/	10/12/
81	Country tiling double					5/ /	9/ /	6/4/	
82	Mangalore tiling								
83	Galvanized corrugated sheet iron roof 20 B W G		32 8/	37/ /		34/ /	38 /		
84	Mud and mat roof		4/8/		4 8	3/ /			
85	Mud roofing 6 on tiles		9/ /		10 /				
86	Terraced roofing of tiles with 5 of fine concrete and pointed underside		15/ /		16/ /	16/4/			
87	LeMesurier roofing plain sheets			26/ /					
	Ceiling								
88	*Pine wood ¾ rebated &c*		23/8/ ¾ Deoda	17/4/ 1 Bar	18/ / 1 Deoda	18/8/ ¾ Deodar	19 / ¾ Deodar	18/8	20/ 1 Chir
89	Cloth including frames complete		8/ /	8/ /	5/12/	5/12/	5/14/	7/ /	6/ /
90	Lathe and plaster		8/ /	8/ /					
	Road Metalling								
91	Collection of kankar	% c ft			6 /	14/8/ to 15/		7/ /	
92	stone metal		8 /	4/8/		12/ /	5/4/		5/ /
93	Consolidation of kankar				1/4/	1/8/	-	1/ /	2/ /
94	stone metal		2/ / (S P)	2 8/ (B P)		1/12/	2/8/		2/ /
	Miscellaneous								
95	Punkahs barrack ordinary without fringes Mortimer's system	r ft							

PRINCIPAL STATIONS IN THE MILITARY WORKS SERVICES

Bengal				Madras				Bombay			
Allahabad	Lucknow	Fort William	Darjeeling	Secunderabad	Madras	Bangalore	Wellington	Quetta	Poona	[illegible]lgaum	Aden
2 2/	2 2	2 12	3 1		–		2 8	2 /	2 12	1/8	2 8/
/8/	6	6	8 6	1	8	4	1	5 6	/12	/10/	/7/
1/ /	12	/10	14/	1/8	1./	[illegible]	1 8/	/11/	1/8/	1/4/	/10/
/4/	/4/				9	8	12/	/6 6	6	/10/	/8/
/6/	6 6			1[illegible]	15	1	1 4		12	1/4	/12/
/1/	1	6		2	[illegible]	1/9	1	/1	1/		/ /3
4	4	2 6			3/	2	/4 6	3 6			3/3
4	4	3 6			3 6	2 9	5	4 6	/4 2		/5
18/ /	15 8			3 /					–		
9/ /	8 /			18							
6 / single	6 single	9		20	10	15 6	19 8		18' /	11/ / single	
		18 8		15	15 4/	11/	26 4/ with battens		17/ /	15 /	[illegible] /
		30	40 /	32 /	33/ /	30 /	30/ /	30/ /	2[illegible]/ 2[illegible] B W G	2[illegible] 8 2[illegible] B W G	30 /
								6 /			
		28 /		25	25 8 to 31 8	27/ /					
				–							
20 /	20 /	37 8 ½ teak	24 / 1 M[illegible] tol	17/ /	16 10	1 / Teak	14 [illegible] teak	18	12 /	16 /	24 /
		7 8		9	8		13 /	6	10 /	9 /	13 9
				12 /	5						
6 /	7 /	11/ Jhama			8 gravel	2 5 gravel	3 gravel			5 8 laterite	
8 8	14 /	23	6	4	10 8	6 11	12	6	5 [illegible]	4	[illegible] and coral lat[illegible]
1 8	1 6	1 8			1 – gravel		2 – gravel			1 6	
2 4	2 4	2 8		1 2	1 4		4	2 [illegible]	9 s.ft (S.I.)	1 6	
•					1 8				12		

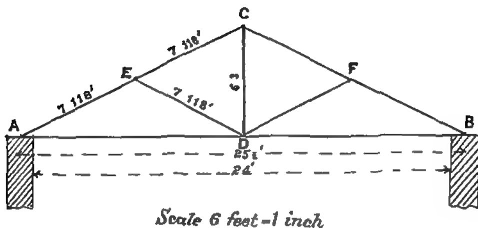
GENERAL INDEX.

PART VI.

PLATES.

FIG. 1.

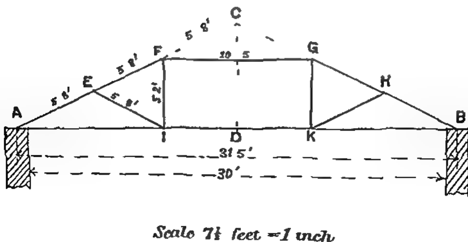
EXAMPLE III.



Scale 6 feet = 1 inch

FIG. 2.

EXAMPLE IV.



Scale 7½ feet = 1 inch

EXAMPLE VIII

Fig 1

A–12 FEET VERANDAH

Scale 3 feet = 1 inch

Fig 2

B–10 FEET VERANDAH

Scale 3 feet = 1 inch

C-EXAMPLE VIII.

Fig. 3.

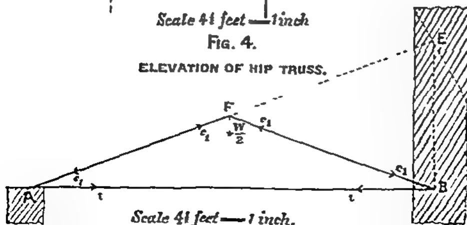
HIP RAFTER

PLAN

Scale 41 feet — 1 inch

Fig. 4.

ELEVATION OF HIP TRUSS.



Scale 41 feet — 1 inch.

IX

g 4

lbs=1)

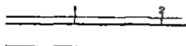
STRESS

kf and hi are ties in diagram fhijkf for point C, also lm in diagram hlmnoh for point D

$\frac{W_1}{4}$ $\frac{W_1}{4}$ $\frac{7W_1}{8}$ $\frac{W_1}{8}$

$\frac{W_1}{4}$ $\frac{W_1}{8}$ $R=\frac{3W_1}{4}$

Scale for Stress Diam



EXAMPLE X

Fig 1

C $\frac{W}{2}$ B D


Scale – 2 feet – 1 Inch

EXAMPLE XI

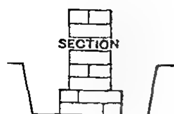
Fig 2

C D B E F $\frac{1}{3}$W $\frac{1}{3}$W $\frac{1}{3}$W


Scale – 3 feet = 1 Inch

BRICK BOND IN WALLS.

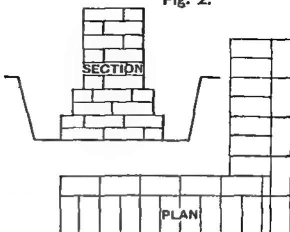
Fig. 1.



PLAN

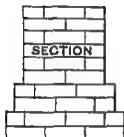
ONE BRICK

Fig. 2.



ONE AND A HALF BRICKS

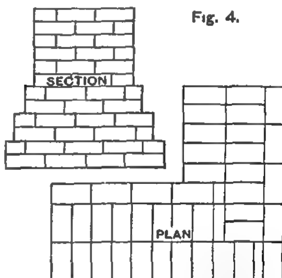
Fig. 3.



PLAN

TWO BRICKS

Fig. 4.



TWO-AND A HALF BRICKS

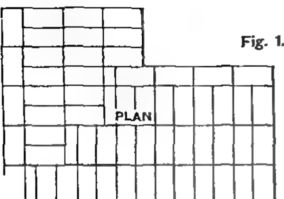
Fig. 5.

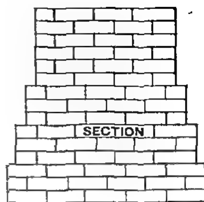
N

E I N

BRICK BOND IN WALLS.

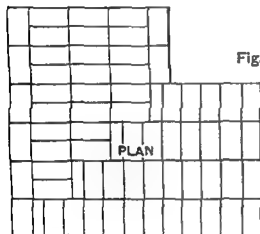
Fig. 1.

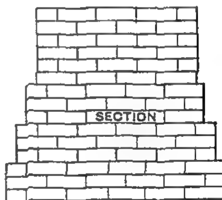




THREE AND A HALF BRICKS.

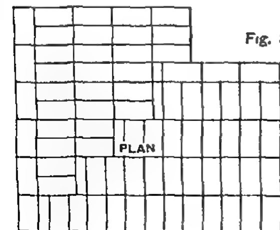
Fig. 2.

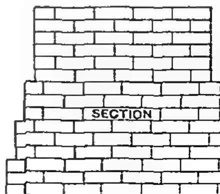




FOUR BRICKS.

Fig. 3.





FOUR AND-A-HALF BRICKS.

BRICK ARCHES.

Fig. 1.

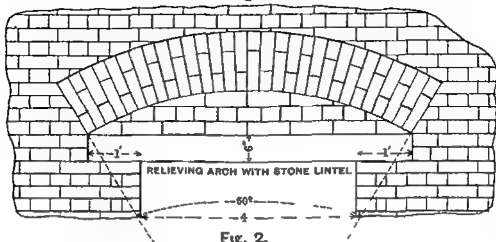


Fig. 2.

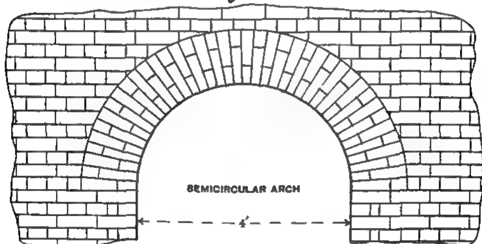
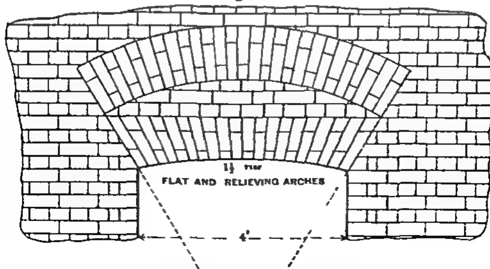
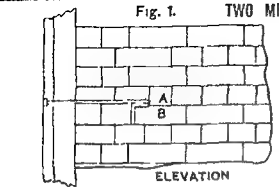


Fig 3.

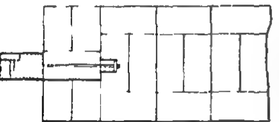


TWO METHODS OF FIXING DOOR FRAMES.

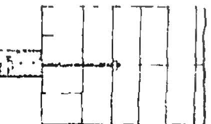
Fig. 1.



ELEVATION



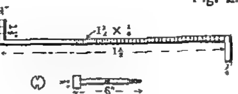
Lower course at B



Upper course at A

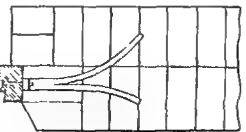


Fig. 2.

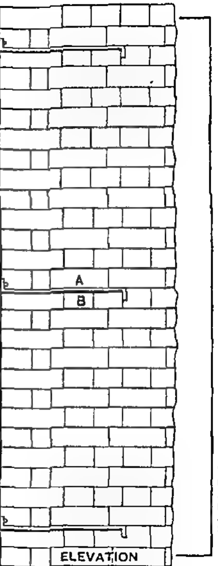




Upper course at A



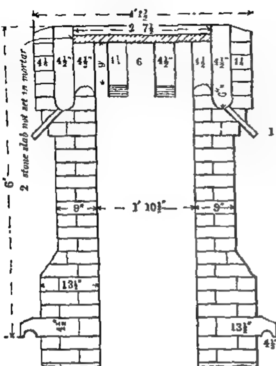
Lower course at B



ELEVATION

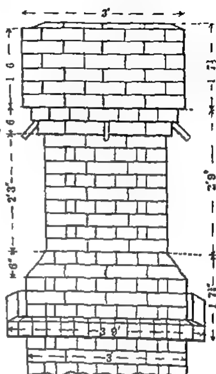
CHIMNEY TOP.

Fig. 1.



SECTION

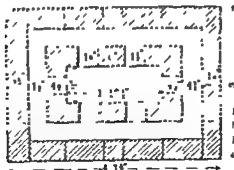
Fig. 2.



SIDE ELEVATION.

Fig. 3

PLAN



No smoke flue should have a less sectional area than 144 sq. inches.

Scale 2 Feet = 1 Inch



CHIMNEY TOP.

ALTERNATE DESIGN

Fig. 1

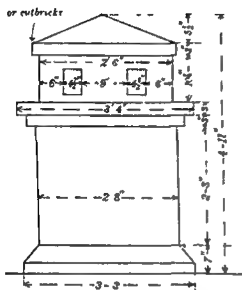


Fig. 2

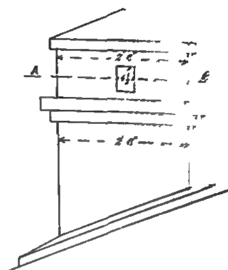
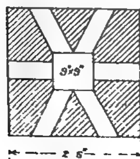


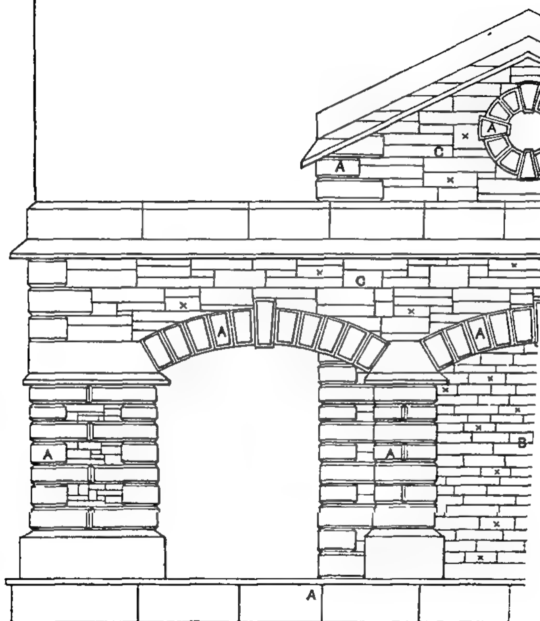
Fig. 3.

PLAN AT A B



Scale 2 feet = 1 inch

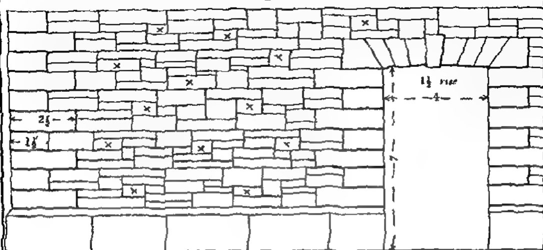
STONE MASONRY. SUITABLE POSITIONS.



A—*Ashlar*
B—*Coursed rubble with ashlar quoins*
C—*Random squared rubble*
Through-bonds marked x

RANDOM RUBBLE.

Fig. 1.



RANDOM SQUARED RUBBLE WITH ASHLAR QUOINS

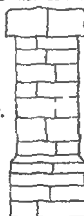
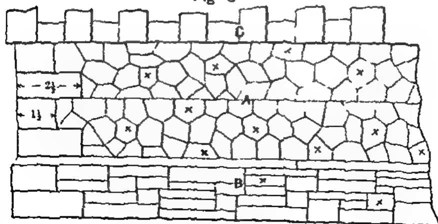
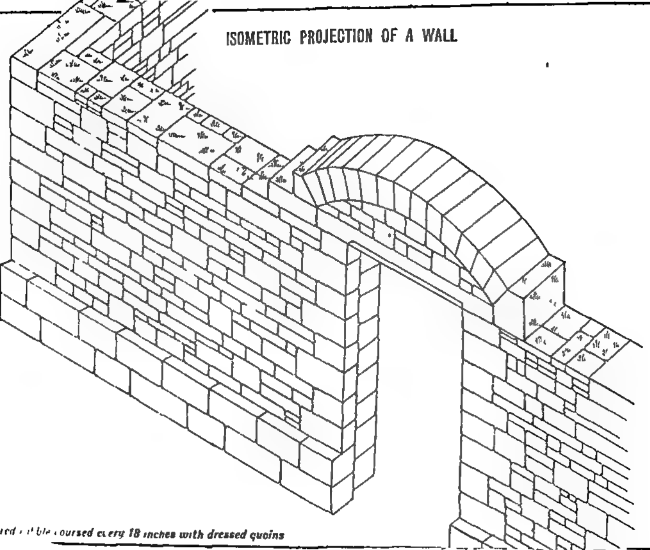
Fig. 2.  SECTION OF WALL

Fig 3



A—Random rubble
B—Random squared rubble
C—Switch coping
Through—b[illegible]s marked thus ×

ISOMETRIC PROJECTION OF A WALL



... coursed every 18 inches with dressed quoins

LIME KILN.

This may be built singly or several can be built together in a block, according to requirements, each kiln will burn about 150 cubic feet per day

Fig. 1
SECTION

Fig. 2

PLAN

MORTAR MILL AND TROUGH FOR MIXING MORTAR

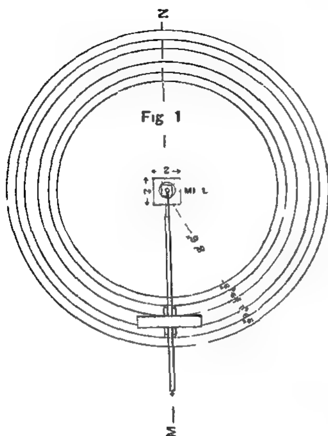


Fig 1

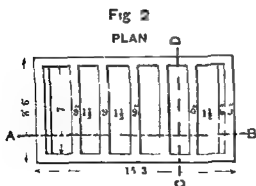


Fig 2
PLAN

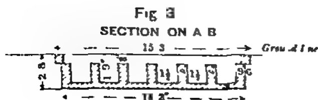


Fig 3
SECTION ON A B

Fig 4
SECTION ON C D

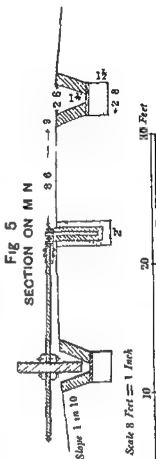


Fig 5
SECTION ON M N



MORTAR MILL—*(continued)*

DETAILS

Fig. 1.

SHAFT

Fig 2

BRICK-ON EDGE

STONE AND SECTION THROUGH TROUGH

Fig. 3.

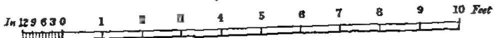
HOOK

Fig. 4.

SPINDLE

TERRACED VERANDAH ROOFING.

SECTION THROUGH VERANDAH



EASY METHODS OF ADDING A VERANDAH TO ANY BRICK WALL

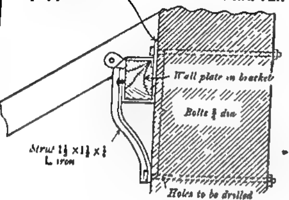


Fig. 5.
VERANDAH RAFTER

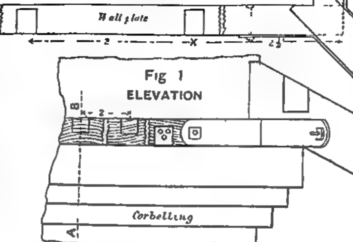


Fig. 4.
PLAN

Fig 1
ELEVATION

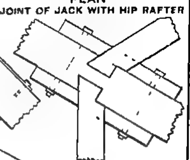


Fig. 3.
PLAN
JOINT OF JACK WITH HIP RAFTER

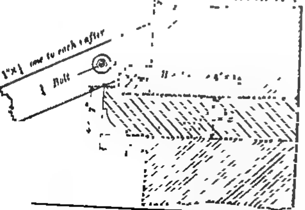
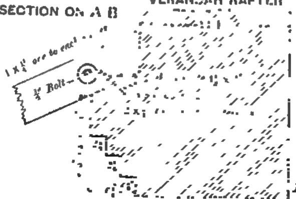
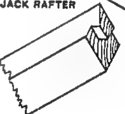


Fig 6.
VERANDAH RAFTER



SECTION ON A B

Fig. 2.
VERANDAH RAFTER

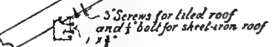


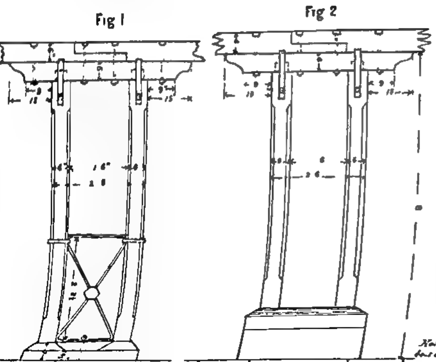
END OF JACK RAFTER

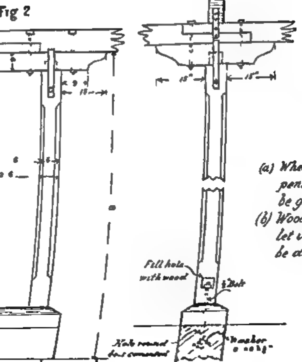


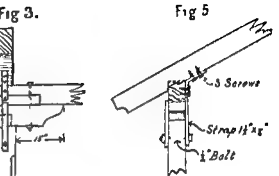
Scale ¾ Inch = 1 Foot

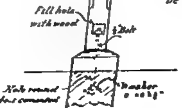
VERANDAH POSTS











Notes

(a) *Where stone bases are too expensive a wooden base may be given bolted to the floor*

(b) *Wooden posts are not to be let into stone bases but to be dowelled*

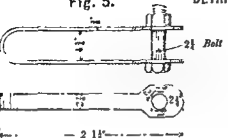


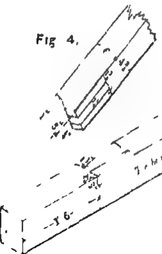
SECTION OF KING POST

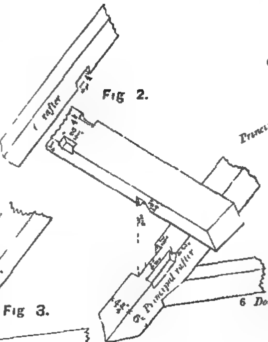
KING POST TRUSS

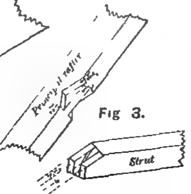
Ridge boards 7" × 1½"
2' 6"
2¼" Screws
Bolts
Ridge pole
C rafter
Bolt
Common rafter
1 Bolt
1¼" Bolt
Strap 2 × ¼
Ridge boards 7" × 1½"
Batten 1½ × 1½
1" Bolt
King pieces double each 6" × 2½
Purlin 6" × 6
Common rafter 4½" × 2½"
Principal rafter 6" × 4½
6" Scantlings
Strut 4" × 4"
1¼" Bolt
2 × ½
Pole plate
Strap 2½ × ⅜
26° 35
10°
6" Dowel, 1½ square, of hard wood
Wood cleat
½" Bolt
Tie Beam 6" × 4½"
Stone wall plate 3"
Clear span 24' 0"

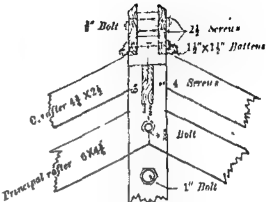
DETAILS OF KING POST TRUSS, PLATE XXVI.

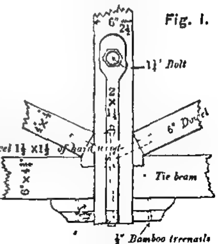








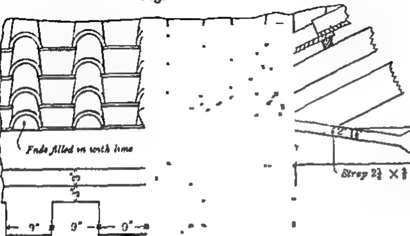




DETAILS OF PLATE XXVI.



Fig. 1



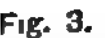
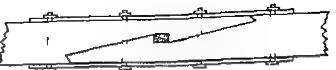


Fig. 3.



JOINTS IN TIE BEAMS



Fig. 4





Fig 2

JOINT IN PURLINS

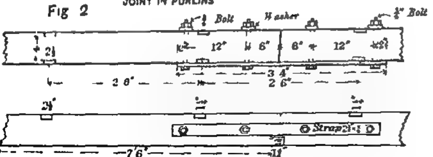




Fig. 5.



DETAIL OF A KING POST TRUSS WITH SINGLE KING POST.

Fig. 1.

JOINT AT FOOT OF KING-POST

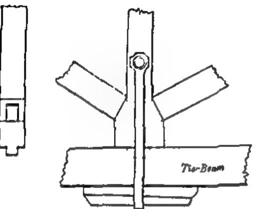


Fig. 2.



ELEVATION OF HEAD OF KING-POST

Fig. 3.

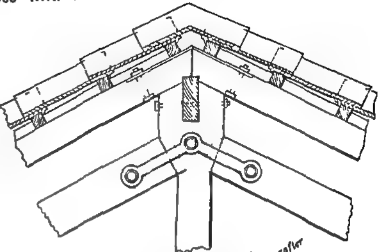


Fig. 4.

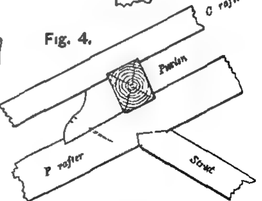


Fig 5

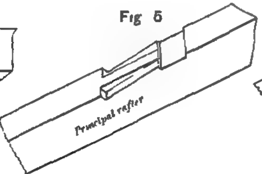


Fig. 6

Ridge pole

FIG I

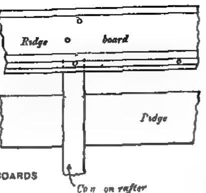


FIG I. METHOD OF FIXING R DGE BOARDS TO SINGLE K NG POST

FIG II

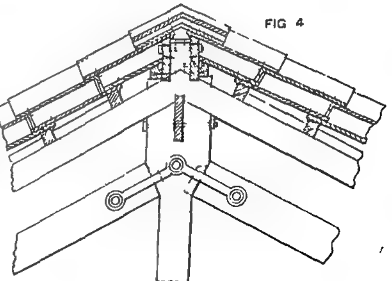
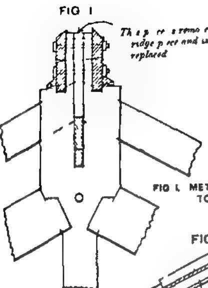
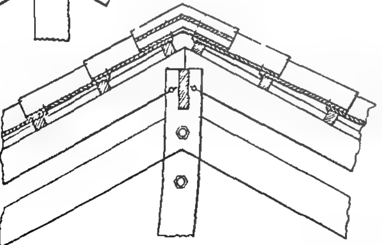


FIG 3



S NGLE ALLAHABAD TIL NG WITH DOUBLE K NG POST

FIG 4



DOUBLE ALLAHABAD TILING W TH SINGLE KING-POST

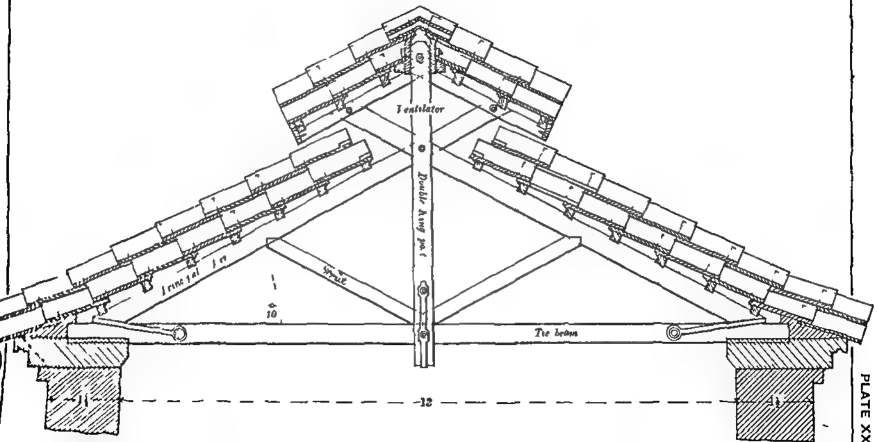
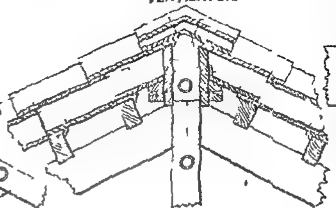
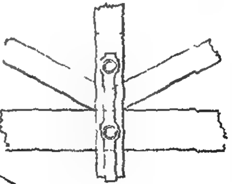
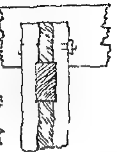

DOUBLE KING POST TRUSS WITH VENTILATOR
Ventilator
Double King post
Strut
Tie beam
10
12

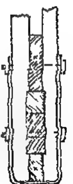
PLATE XXXI

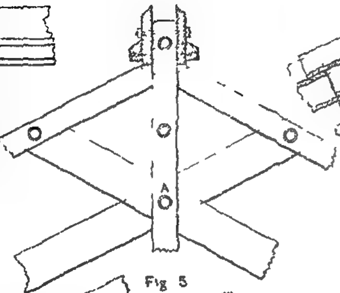
DETAIL FOR PLATE XXXI

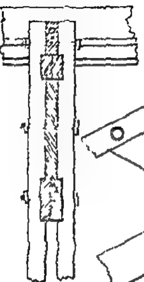


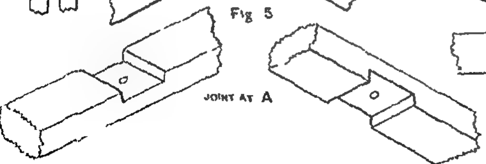












QUEEN-POST TRUSS

Fig 2

Wooden cleat
Ridge boards $1\frac{1}{4}$" × $7\frac{1}{2}$"
$\frac{3}{8}$" bolts
Batten $1\frac{1}{2}$" × $1\frac{1}{2}$"
Ridge pole 2" × 8
Common rafters $2\frac{1}{2}$ × 4"

DETAILS AT A

Fig 1.

Cleat and bolts at every third rafter only

Fig 3

Fig 4

Ridge pole
Common rafter

Fig 1.

A
2" × 8"
Battens $1\frac{1}{2}$" × $1\frac{1}{2}$"
Purlin $3\frac{1}{2}$ × $5\frac{3}{4}$
Bolt $1\frac{1}{2}$ dia
8" × $4\frac{1}{2}$"
$\frac{3}{4}$ dia bolt
B
1 dia
Double Queen post $6\frac{1}{4}$ × $2\frac{1}{4}$"
$2\frac{1}{2}$ × 4
Purlin $3\frac{1}{2}$" × $5\frac{3}{4}$
$4\frac{1}{2}$ × $4\frac{1}{2}$"
$4\frac{1}{2}$ × $6\frac{1}{4}$
10
$1\frac{1}{4}$" dia bolt
1 diameter bolts
C
3" × 4
$4\frac{1}{2}$ × $6\frac{1}{4}$
Wood strut
Bolt $1\frac{5}{8}$" dia
Stone bed plate 4½" × 2 × 6"
Strap 2 × $\frac{1}{4}$"
3" × $\frac{3}{4}$"
SPAN 32 FEET

DETAIL FOR PLATE XXXIII FIG 1.

Fig. 1.

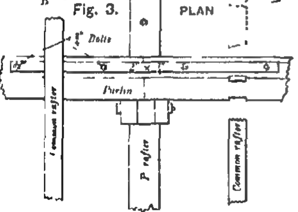


Fig. 2.
SECTION ON A.B. FIG. 1.

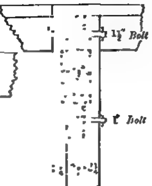
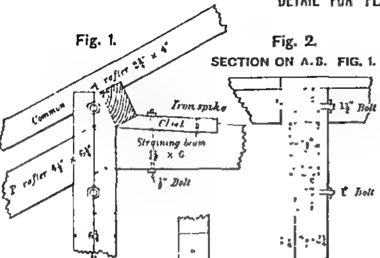


Fig. 3.
PLAN



JOINT AT B

Fig. 4.
ELEVATION

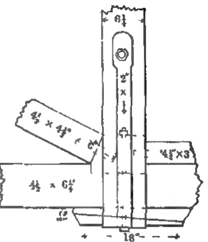


Fig. 5.
SECTION

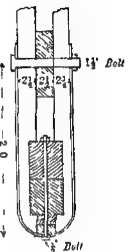
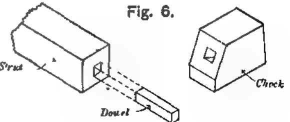


Fig. 6.



JOINT AT C.

HIPPING OF TWO ROOFS AT RIGHT ANGLES.

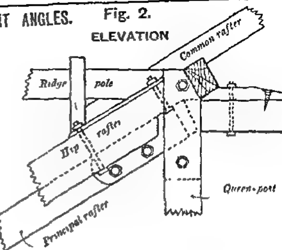
Fig. 1.

ARRANGEMENT OF WOODWORK

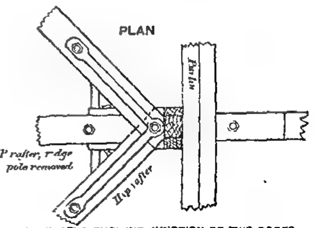
Purlin
A
Common rafter
Queen-post truss
37'
24'
Common rafter
King-post truss

Fig. 2.

ELEVATION



PLAN



DETAIL AT A SHOWING JUNCTION OF TWO ROOFS

CROSS HEAD TO TAKE HIP AND INTERMEDIATE RAFTERS

Fig 1

PLAN

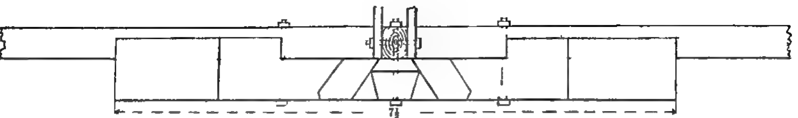


Fig 2

FRONT ELEVATION

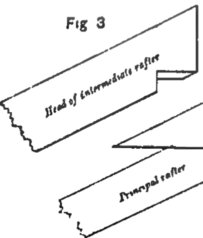
Cross head

King post

Principal rafter

Principal rafter

Fig 3



SIMPLE METHOD OF ROOFING FAMILY QUARTERS.

Fig 1.

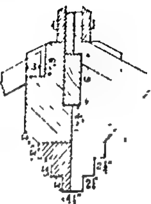
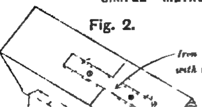


Fig. 2.



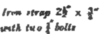


Fig. 3.

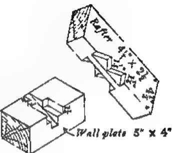
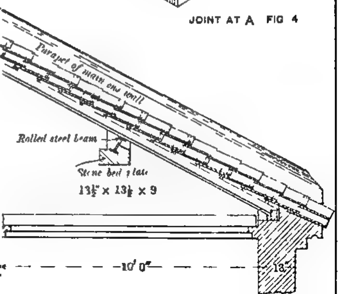
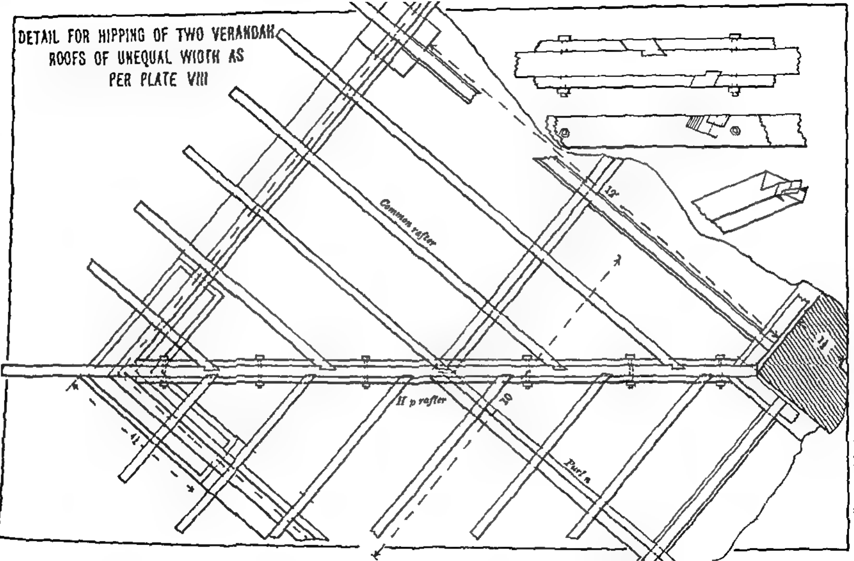


Fig. 4.




DETAIL FOR HIPPING OF TWO VERANDAH
ROOFS OF UNEQUAL WIDTH AS
PER PLATE VIII
Common rafter
12'
11'
20'
14'

VERANDAH IN CONTINUATION OF MAIN ROOF

Fig. 3.

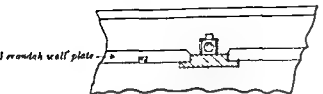


Fig. 2.

ALTERNATIVE METHOD

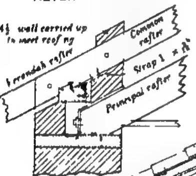


Fig. 1

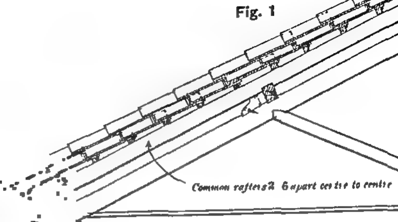
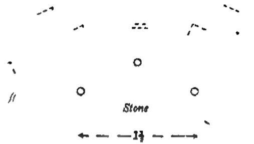


PLATE XXXIX

WALL PLATE ON PARTITION WALL

Scale ½ Inch = 1 Foot





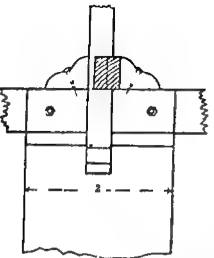
Brickwork

Stone

9

Open space

COUPLED RAFTERS



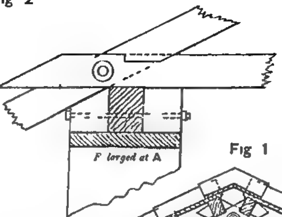


Fig 2

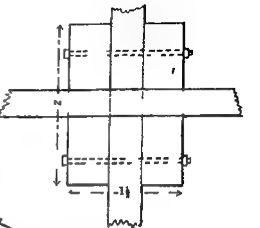
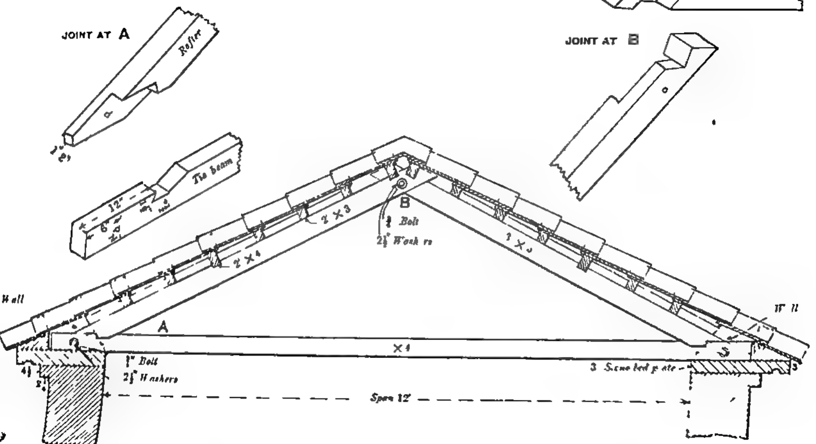


Fig 3
PLAN

Fig 1

PLATE XLII

COUPLED RAFTERS



STEEL TRUSSES.

Fig. 1.

Fig 2

Gusset plates

$3\frac{1}{2}" \times 3\frac{1}{2}" \times \frac{3}{8}"$

1 diameter

$2\frac{1}{2}" \times \frac{1}{4}"$

DETAIL OF STRUT

Fig. 3.

DETAIL AT A

Fig 4

SECTION ON EF

A

B

$1\frac{1}{2}" \times 1\frac{1}{2}"$

$2\frac{1}{2}" \times \frac{1}{4}"$ flat bar

T steel $3\frac{1}{2}" \times 3\frac{1}{2}" \times \frac{3}{8}"$

$3\frac{1}{2}" \times 4\frac{1}{2}"$

$2" \times 4$

Double $2\frac{1}{2}" \times \frac{1}{4}"$ bars

2 dist pieces 1" diamr.

B

$2\frac{1}{2}" \times \frac{1}{2}"$ flat bar

$3\frac{1}{2}" \times \frac{1}{2}"$

$\frac{3}{4}"$ rivets

E

F

Trusses 24' span and 6' 9" apart

STEEL TRUSSES.

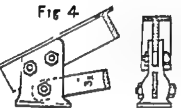


Fig 2
ANGLE IRON PURLIN

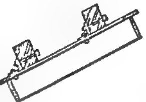


Fig 3
ANGLE IRON BRACKET FILLED WITH WOOD

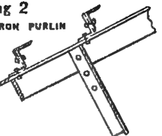
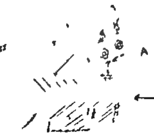


Fig 4
DETAIL AT A





Flat bar 2½" × ¼"

T 4" × 5" × 3/8"

Angle 1¾" × 1¾" × 175'

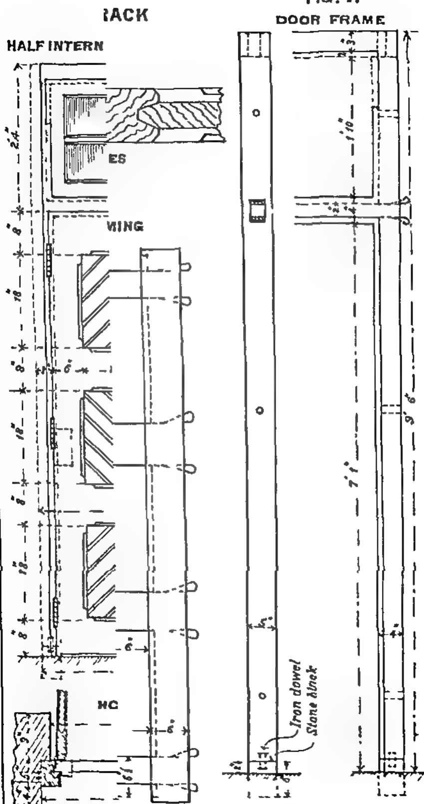
Flat bar 2½" × ¼"

Flat bar 3½ × ½

A

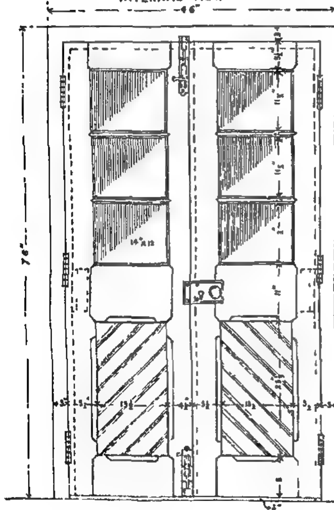
Trusses 24 span and 6 9 apart

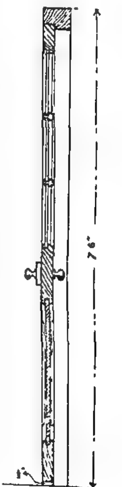
Either methods of Fig 2 or 3 may be used

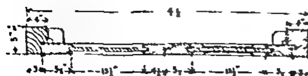

Fig. 7.
DOOR FRAME
RACK
HALF INTERN
ES
WING
HC
Iron dowel
Stone block
9' 6"
7' 1"
1' 10"
2' 4"

DOOR FOR FAMILY QUARTERS









Note
Fanlight as in Plate XLV may be added when necessary

OUT-HOUSE DOORS.

Fig. 4.
JOINTS IN PANEL

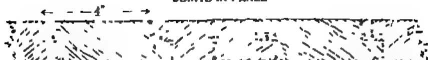


Fig. 1.
EXTERNAL VIEW

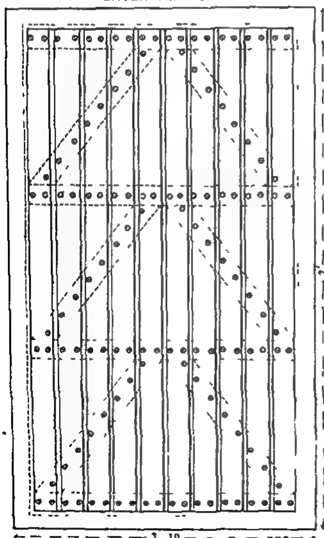


Fig. 2.
VERTICAL SECTION



Fig. 3
HORIZONTAL SECTION

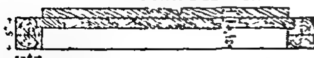
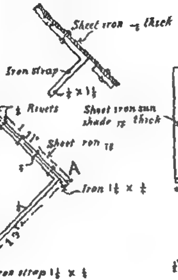
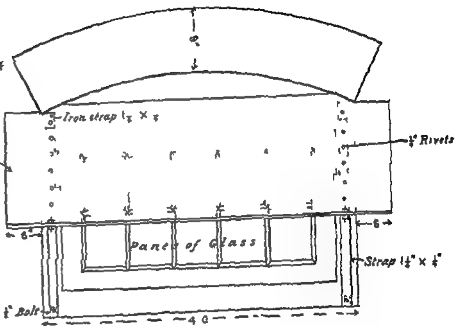
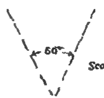


PLATE XLVIII

IRON SUNSHADE







STONE SUNSHADE OVER CLERESTORY WINDOWS.

Fig. 1.

PLAN.

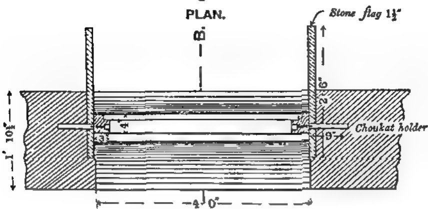


Fig. 2.

SECTION ON A B.

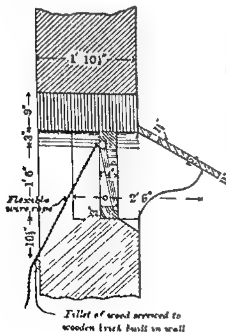
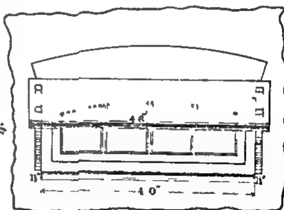


Fig. 3.

FRONT ELEVATION





ARM RACK FOR ALL ARMS OF THE SERVICE.

Scale for Figs 1 2 7 8 and 10

In 12 9 6 3 0 1 2 3 feet

12 9 6 3 0

Scale for Figs 3, 4, 5 and 6

Fig 1

Fig 2

Fig 3

Plank

Iron bar

Fig 4

Fig 5

Fig 6

Fig 7

Fig 8

2½" *Screws*

Fig 9

Fig 10

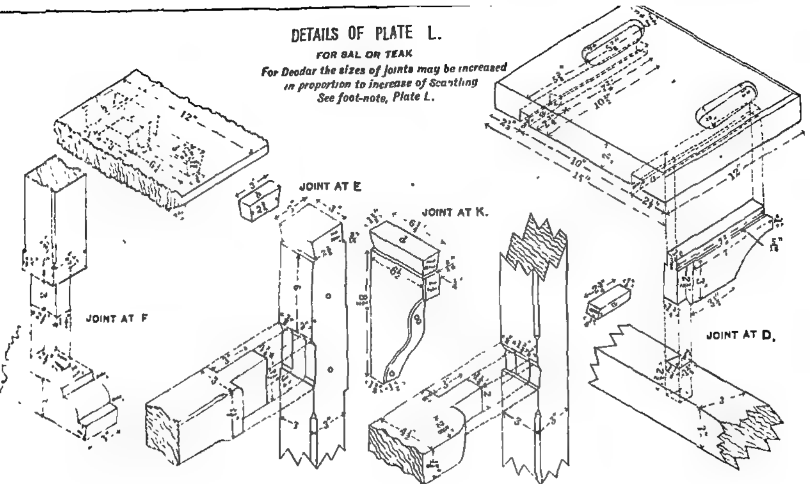
Floor

Block of wood 3 × 3

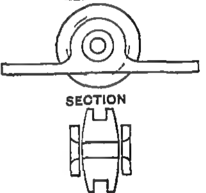
Bolt

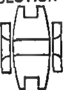
Note For details, see Plate LI

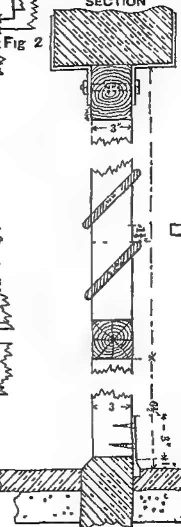
The above dimensions are for Sal or Teak. For Deodar piece D and the two uprights K, K should be

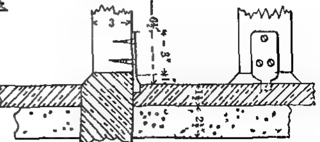

DETAILS OF PLATE L.
FOR SAL OR TEAK
For Deodar the sizes of joints may be increased in proportion to increase of Scantling
See foot-note, Plate L.
JOINT AT E
JOINT AT K.
JOINT AT F
JOINT AT D.
Scale
In 12 9 6 3 0 1 foot

WOODEN LOUVRES









PART ELEVATION

Fig 2

Fig 1.

SIDE VIEW OF STOP

Stop

Upper story louvres

Sliding

Fixed frame

Sliding frame

MORTIMER'S PUNKAH

Fig 1.
FRONT ELEVATION.

Tie-beam

⅝" Hook

Brass thimble

⅝" Dia

Log line or cotton rope ½" circumference

⅝ Suspending rods

Height about 10 feet—rather higher is better

—3

Brass thimble

Longitudinal piece 2 × 1½

Wooden runner

8 feet from floor

2 6

6"

3

1 6"

5½"

Hinge

Clip

Punkah bar 3 × 1½

3" Hinge

Clip

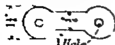
Punkah fringe

Fig 2.
SECTION.



Fig 3.
PLAN OF RUNNER

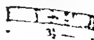
for raising and lowering punkah



Scale for Figs. 1 and 2—1 Foot = ⅛ Inch

Scale for Figs. 3 and 4—1 Inch = ½ Inch

Fig 4.
ELEVATION



DETAILS OF MORTIMER'S PUNKAH

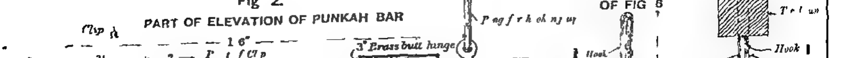


Fig 2.
PART OF ELEVATION OF PUNKAH BAR

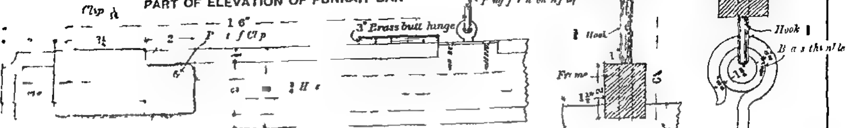


Fig 1
PART PLAN OF PUNKAH BAR

Fig 4
SECTION ON C D

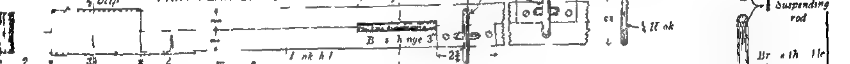




Fig 8
ELEVATION ON G H
OF FIG 6

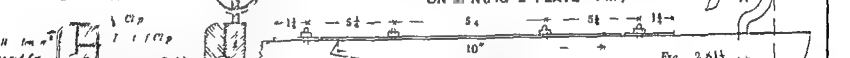


Fig 5
SECTION ON E F

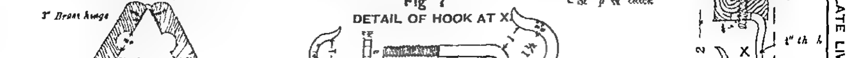


Fig 6
SIDE ELEVATION OF LONGITUDINAL PIECE
ON M N (FIG 2 PLATE LIII)

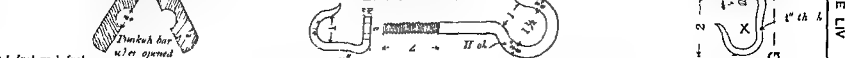


Fig 7
DETAIL OF HOOK AT X

DETAILS OF MORTIMER'S PUNKAH

Fig 2

PART OF ELEVATION OF PUNKAH BAR

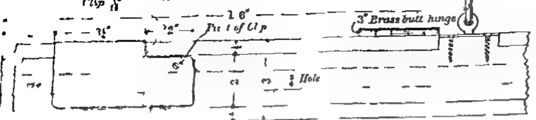


Fig 1

PART PLAN OF PUNKAH BAR

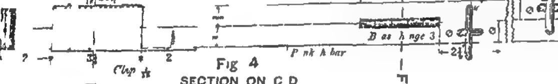


Fig 8

ELEVATION ON G H OF FIG 8

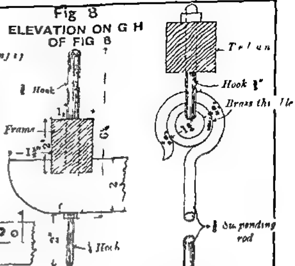


Fig 4

SECTION ON C D



Fig 3

SECTION ON A B

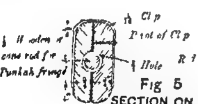
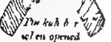


Fig 5

SECTION ON E F

Scale 1 Inch = ¼ Inch

Fig 6

SIDE ELEVATION OF LONGITUDINAL PIECE ON M N (FIG ■ PLATE LIII)

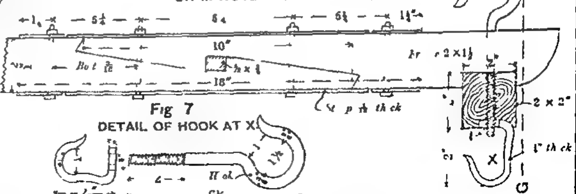
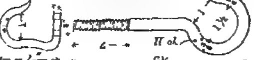


Fig 7

DETAIL OF HOOK AT X



IRON CHULAS FOR COOK-HOUSES

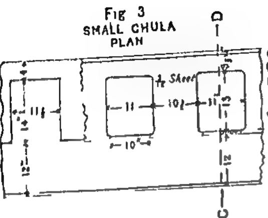


Fig 3
SMALL CHULA
PLAN

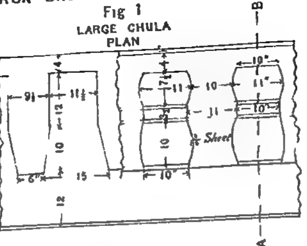


Fig 1
LARGE CHULA
PLAN

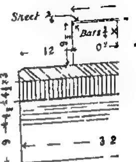


Fig 2
SECTION

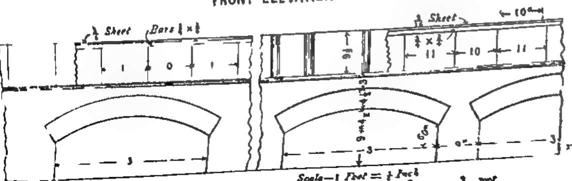


Fig 5
FRONT ELEVATION

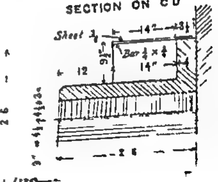


Fig 4
SECTION ON CD

SPECIAL FLAT ALLAHABAD TILES.



Fig. 5.
ELEVATION

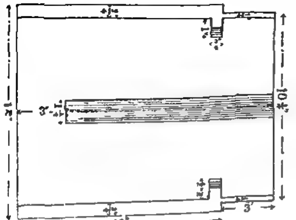


Fig. 4.
PLAN.

STRONG TILE FOR UPPER LAYER

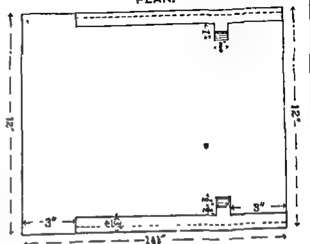


Fig. 2.
ELEVATION.

Fig. 1.
PLAN.

TILE FOR USE IN LOWER LAYER TO KEEP OUT DUST.

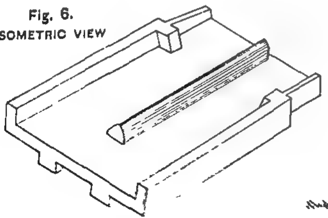


Fig. 6.
ISOMETRIC VIEW

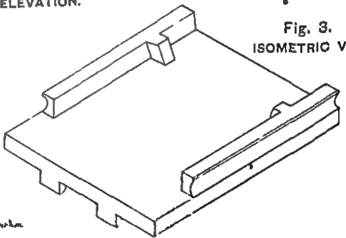
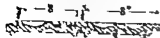


Fig. 3.
ISOMETRIC VIEW.

MANGALORE TILING

Scale 1 Inch = 1 Foot

CROSS SECTION
WHEN ADJUSTED



UPPER SIDE



LOWER SIDE





LONGITUDINAL SECTION
WHEN ADJUSTED

MANGALORE TILING OVER PLANKING AND DAMMER.

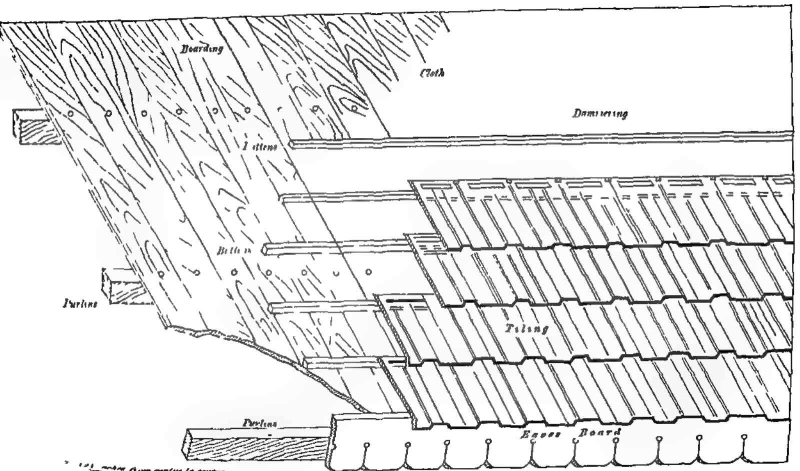


FIG 4

SECTION ON N O.



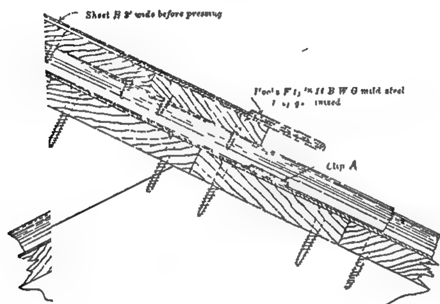
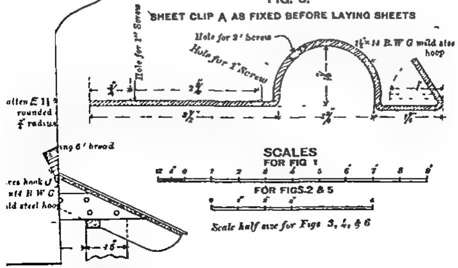


FIG. 6.

SHEET CLIP A AS FIXED BEFORE LAYING SHEETS



SCALES

FOR FIG 1

FOR FIGS.2 & 5

Scale half size for Figs 3, 4, & 6

Batten K

Batten E

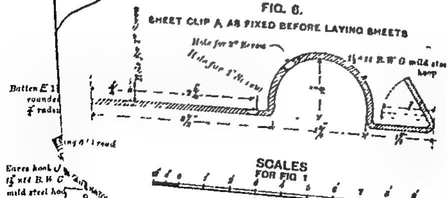
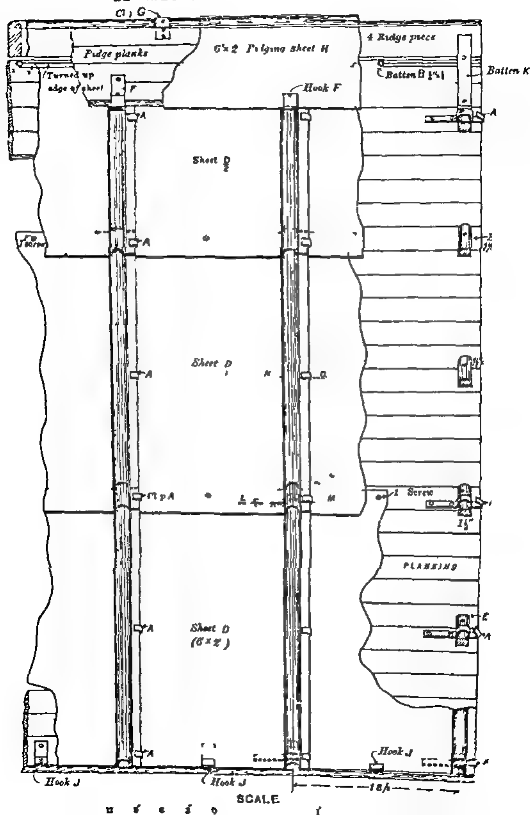


FIG. 6.

SHEET CLIP A AS FIXED BEFORE LAYING SHEETS

LE MESURIER SYSTEM OF ROOFING





NOTE

Fillet 3 × 1½

Batten 2" × 1½

...heet 2" wide ...th screws

←K

Roll A

Batt en B *2" × 1½*

Fi

Fig. 5.

Clip M

Clip L

Roll A

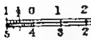
Batten 1½

Clip M

1" Plank

Rafter

Scale f



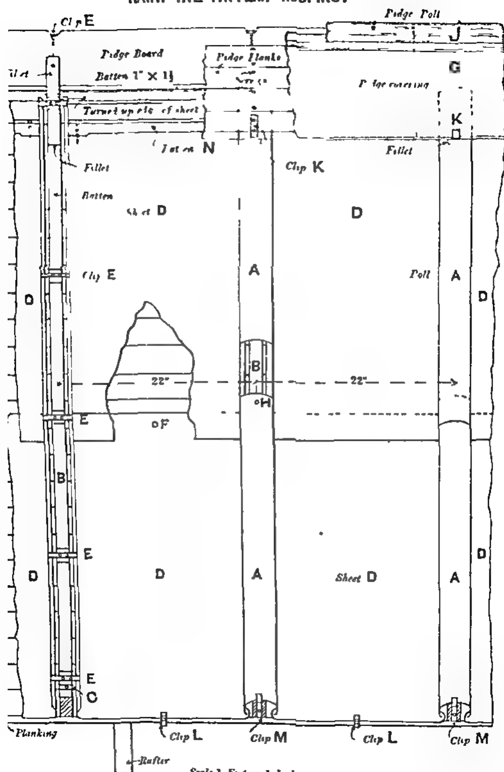
Scale fo



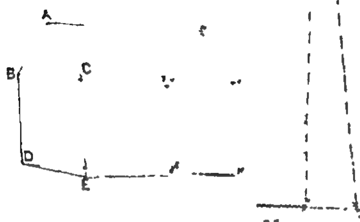
Scale for Figs 5 & 6–1 Foot = 1 Inch

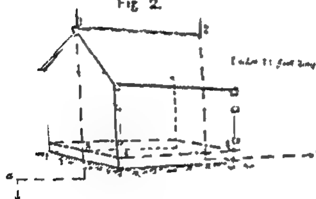


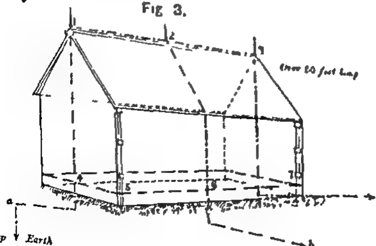
Scale for Fig 3–1 Foot = 3 Inches.


NAINI TAL PATTERN ROOFING.
Clip E
Ridge Roll
J
Ridge Board
Ridge Flanks
G
Batten 1" X 1½
Turned up edge of sheet
K
Batten N
Fillet
Fillet
Clip K
Batten
Sheet D
D
A
Clip E
Roll
A
D
D
B
22"
22"
H
E
F
B
E
D
D
D
A
Sheet D
A
E
C
Planking
Clip L
Clip M
Clip L
Clip M
Rafter

ARRANGEMENT OF CONDUCTORS [illegible]



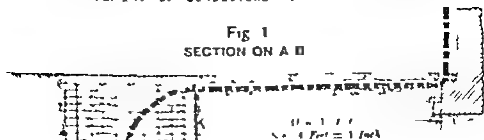




Scale about 25 feet to an inch

ARRANGEMENT OF CONDUCTORS FOR MAIN MAGAZINES

Fig 1
SECTION ON A B



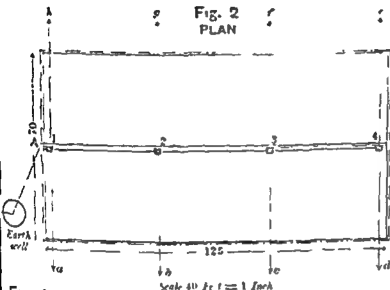
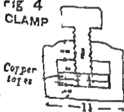




Fig 3
END ELEVATION

Fig 4
CLAMP



Scale for Fig 4—1 Foot = 6 Inches
Scale for Figs 5 6 & 7 —1 Foot = 4 Inches

Fig. 7.
SECTION ON C D.

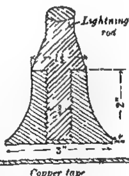


Fig. 6.
SECTION ON A.B

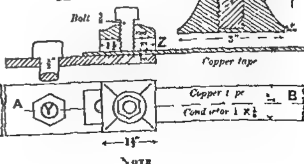
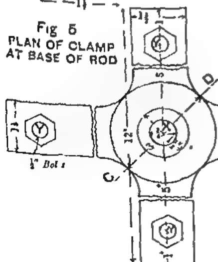


Fig 5
PLAN OF CLAMP AT BASE OF ROD



NOTE

X Screw socket for rod must be screwed tightly home
Y Bolts to atta[illegible] f[illegible] building
Z One or more [illegible] can be lengthened [illegible] in clamps as sketched

SECTION OF HALF COMPANY BARRACK FOR BRITISH INFANTRY, MANDALAY.

DETAIL OF STRAP AT D.



Scale — 10 Feet — 1 Inch

DETAILS OF JOINTS OF PLATE LXVII

Fig 3
DETAIL AT C

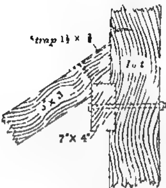
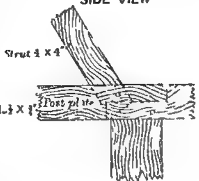


Fig
DETAIL AT B
SIDE VIEW



END VIEW



Fig 1
DETAIL AT A



Fig. 4
DETAIL AT E

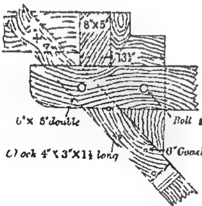


Fig 5
SECTION ON A B

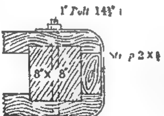


Fig 6
DETAIL AT F

Fig 7
DETAIL AT I

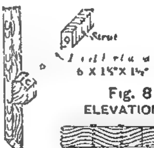
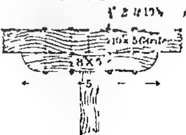


Fig. 8
ELEVATION AT G



Fig 9
ELEVATION AT H



PATENT CHAIN AND WEIGHT SELF-CLOSING STANDPOST.

MANUFACTURED BY GLENFIELD & Co OF KILMARNOCK

Fig. 3. ELEVATION

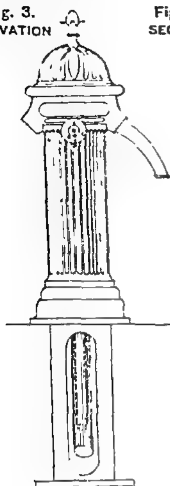
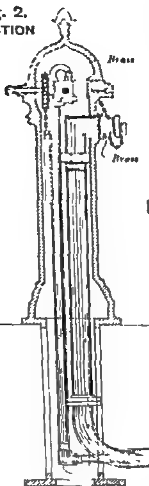
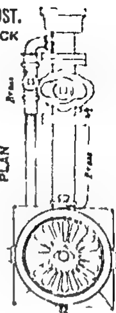


Fig. 2. SECTION





Scale 1 Foot = ½ Inch

Fig. 4.

PLAN OF PLATFORM AND MUSSACK STAND

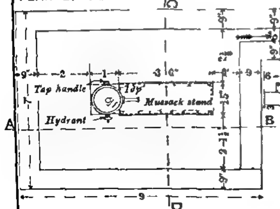


Fig. 5.

SECTION ON A.B.

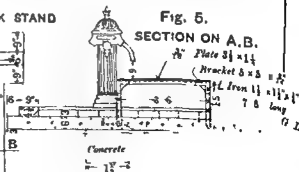
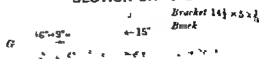


Fig. 6.

SECTION ON C D



Scale for Figs 4, 5, & 6 – 4 Feet = 1 Inch.

CLIP FOR FIXING CORRUGATED IRON ROOFING

Fig. 1

SECTION ON A B



Fig 2

CORRUGATED IRON REMOVED

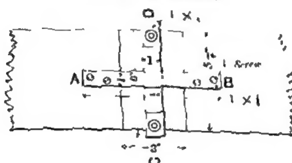
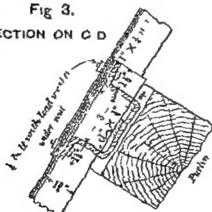


Fig 3.

SECTION ON C D



N.B. *The depth (interior) of the Clip marked 2" is ¼ more than the depth of a corrugation*